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Credit Market Competition and Capital Regulation*

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Abstract

It is commonly believed that equity finance for banks is more costly than deposits. This suggests that banks should economize on the use of equity and regulatory constraints on capital should be binding. Empirical evidence suggests that in fact this is not the case. Banks in many countries hold capital well in excess of regulatory minimums and do not change their holdings in response to regulatory changes. We present a simple model of bank moral hazard that is consistent with this observation. In perfectly competitive markets, banks can find it optimal to use costly capital rather than the interest rate on the loan to guarantee monitoring because it allows higher borrower surplus.

Keywords: credit market competition, monitoring, loan rates, capital, bank monitoring

JEL codes: G21, G31, D4

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1 Introduction

A common justification for capital regulation for banks is the reduction of bank moral hazard. If banks hold a low level of capital, there is an incentive for them to take on excessive risk. Given the widely accepted view that equity capital is more costly for banks than other forms of funds, the common result in many analyses of bank regulation is that capital adequacy standards are binding as banks attempt to economize on the use of this costly input.

In practice, however, it appears that banks often hold levels of capital well above those required by regulation and that capital holdings have varied substantially over time in a way that is difficult to explain as a function of regulatory changes. For example, Berger et al. (1995) report that the ratios of equity to assets of US banks fell from around 40-50 percent in the 1840's and 1850's to 6-8 percent in the 1940's, where they stayed until the 1980's. Comparing actual capital holdings to regulatory requirements, Flannery and Rangan (2007) suggest that banks' capital ratios have increased substantially in the last decade, with banks in the US now holding capital that is 75% in excess of the regulatory minimum. Similar cross-country evidence is provided in Barth et al. (2005) (see Figure 3.8, p. 119).[1] In search of an explanation of the capital buildup in the US throughout the 1980's, Ashcraft (2001) finds little evidence that changes in banks' capital structure are related to changes in regulatory requirements. Barrios and Blanco (2003) argue that Spanish banks' capital ratios over the period 1985-1991 were primarily driven by the pressure of market forces rather than regulatory constraints. Also, Alfon et al. (2004) report that UK banks increased their capital ratios in the last decade despite a reduction in their individual capital requirements, and operate now with an average capital buffer of 35-40 percent. Finally, Gropp and Heider (2007) do not detect a first order effect of regulation on banks' capital holdings.

In this paper we develop a model of bank capital consistent with the observation that banks hold high levels of capital which may change independently of regulation. Our model is based on two standard assumptions. First, banks' capital structures may have implications for their ability to attract borrowers. Second, banks perform a special role as monitors. With

[1] A recent study by Citigroup Global Markets (2005) finds that "... most European banks have and generate excess capital," with Tier 1 ratios significantly above target.

these two features, we show that market forces can lead banks to hold levels of capital well above regulatory minimums even when capital is relatively costly.

In our one-period model of bank lending, firms need external financing to make productive investments. Banks grant loans to firms and monitor them, which helps improve firms' performance. Specifically, we assume that the more monitoring effort a bank exerts, the greater is the probability that a firm's investment is successful. Given that monitoring is costly and banks have limited liability, banks are subject to a moral hazard problem in the choice of monitoring effort and need to be provided with incentives. One way of doing this is through the amount of equity capital a bank has. Capital forces banks to internalize the costs of their default, thus ameliorating the limited liability problem banks face due to their extensive reliance on deposit-based financing. A second instrument to improve banks' incentives is embodied in the interest rate on the loan. A marginal increase in the loan rate gives banks a greater incentive to monitor in order to receive the higher payoff if the project succeeds and the loan is repaid. Thus, capital and loan rates are alternative ways to improve banks' monitoring incentives, but entail different costs. Holding capital implies a direct private cost for the banks, whereas increasing the loan rate has a negative impact only for borrowers in terms of a lower profit from the investment. Which incentive instrument (or combination of instruments) is used in equilibrium will depend on how surplus is allocated between banks and borrowers.

We consider two distinct cases. In the first, we assume that the bank operates in a monopolistic loan market. The second case we consider is where there is a perfectly competitive loan market so that borrowers' surplus is maximized.

We start with the benchmark where there is no deposit insurance. In this case if the bank's projects are unsuccessful the bank defaults and depositors do not receive anything. In order for depositors to be willing to provide their funds to the bank they require a premium in non-default states. The higher the probability of default the higher this premium needs to be. This mechanism provides an additional incentive for banks to monitor since by doing so they can lower their cost of funds. In the case of monopoly, since the bank obtains all the surplus, it will exert the maximum monitoring effort as long as intermediation is profitable. When project returns are high the loan rate provides all necessary incentives.

When project returns are lower, capital also becomes necessary. The market allocation is constrained efficient in the sense that a regulator attempting to maximize social welfare by imposing capital controls cannot improve on it.

With perfectly competitive markets where borrowers obtain the surplus and there is no deposit insurance the results are quite different. Here competitive market pressures ensure that banks will use more capital than in the monopoly solution. The reason is that, to ensure maximal monitoring, borrowers are better off with a lower loan rate and higher capital. The lower loan rate directly benefits borrowers while the higher level of capital affects them only indirectly through the bank's participation constraint. As a result the market solution is often inefficient because the market only cares about maximizing borrower surplus. Here, a regulator can improve social welfare by imposing regulations to *lower* the amount of capital banks use.

The case where there is deposit insurance is more complex to analyze. The presence of deposit insurance implies that the degree of monitoring does not affect a bank's cost of deposits. Thus deposit insurance blunts banks' incentives to monitor and as a result banks' portfolios are more risky. This potentially provides a role for capital regulation. By requiring banks to hold a minimum amount of capital it is possible to provide incentives to monitor and reduce firm risk. Indeed this is one classic argument for having capital regulation - to offset the incentive problems created by deposit insurance. In the case of monopoly we show that there is some merit to this argument. For low values of project returns and low costs of equity capital a regulator can improve social welfare compared to the market solution by requiring banks to hold more capital than they would voluntarily do. However, for other regions of the parameter space the allocation is constrained efficient. In the case with competition and deposit insurance the market again usually provides incentives to use too much capital. For large parts of the parameter space the problem, as in the no deposit insurance case, is that banks use too much capital. For a relatively small part of the parameter space banks use too little capital. For the remainder the market is constrained efficient. Thus the results in this case are similar to those with no deposit insurance. However, the "excess capital" is less likely to occur than without deposit insurance as deposit insurance blunts monitoring incentives, thus increasing the scope for capital regulation.

Our paper is consistent with the observation that banks hold capital that is well in excess of capital requirements as we observe in practice. It is also consistent with the fact that changes in capital regulation do not affect banks' capital structures as found by Ashcraft (2001), Barrios and Blanco (2003) and Alfon et al. (2004). These findings suggest that market discipline can be imposed not only from the liability side, as has been stressed in the literature on the use of subordinated debt (for a review, see Flannery and Nikolova, 2004), but also from the asset side of banks' balance sheets.

Our model also provides some interesting insights into the role of deposit insurance. A standard rationale for deposit insurance is that it helps prevent bank runs as in Diamond and Dybvig (1983) and coordination failures among depositors which may prevent the creation of banks as in Matutes and Vives (1996). Our model provides another rationale. Although in most situations deposit insurance lowers social welfare, we show that in some cases it can improve the allocation of resources by reducing the use of costly capital. Without deposit insurance, limited liability implies that banks must pay a high rate of interest to compensate for losses when they default. In order to assure depositors that default will not occur banks use capital when expected project returns are low. This effect is not present when there is monopoly with deposit insurance so banks use no capital. This reduction in the use of capital can lead to an improvement in social welfare if the cost of capital is sufficiently high. This result is related to the one in Morrison and White (2006) in that deposit insurance helps correct a market failure and expands markets. In their work the market failure comes from the sharing of surplus between banks and depositors. In contrast, in our model the market failure is the inability to contract on bank monitoring directly and the necessity of using the interest rate and capital to provide incentives.

We extend our model in a number of directions. First, we develop a version of the model where borrowers obtain private benefits and there is an incentive problem as in Holmstrom and Tirole (1997). Bank monitoring is necessary to reduce the private benefits and alleviate the borrower's incentive problem. We argue that effects similar to those described above with regard to banks' use of capital will hold in this version. Second, we consider intermediate market structures between monopoly and competition where only the interest of one group is taken into account. Our main results remain valid in this case. Third, we analyze the case

where banks can choose between relationship and transactional lending. The first refers to the monitored loan we have considered so far, and the second to a loan with a lower probability of success but a higher payoff in case of success. We show that capital regulation increases the attractiveness of relationship loans relative to transactional loans. This is because capital improves banks' monitoring incentives when they are engaged in relationship lending but it represents a pure cost in the case of transactional lending. Finally, we study the case where banks have a franchise value from remaining in business as a way of introducing some simple dynamic considerations. We find that franchise value and capital are substitute ways of providing banks with monitoring incentives. There is thus less need for capital regulation when banks enjoy a large franchise value from remaining in business.

The paper has a number of empirical implications. First, the model suggests that banks keep higher levels of capital when credit markets are competitive, in line with the empirical finding in Schaeck and Cihak (2007) that banks hold higher capital ratios when operating in a more competitive environment. Second, our analysis predicts that increased capital requirements imply a shift in banks' portfolios away from transactional lending towards more relationship lending. Third, the analysis suggests that capital and franchise values are substitute ways to improve banks' monitoring incentives. Finally, our model offers some cross-sectional implications concerning banks' capital holdings and firms' sources of borrowing. Banks engaged in monitoring-intensive lending should be more capitalized than banks operating in more transactional lending. To the extent that small banks are more involved in more monitored lending to small and medium firms, the model predicts that small banks should be better capitalized than larger banks, in line with the empirical findings in Alfon et al. (2004) and Gropp and Heider (2007). Similarly, firms for which monitoring adds the most value should prefer to borrow from banks with high capital. Billett et al. (1995) find that lender "identity," in the sense of the lender's credit rating, is an important determinant of the market's reaction to the announcement of a loan. To the extent that capitalization improves a lender's rating and reputation, these results are in line with the predictions of our model.

Recent research on the role of bank capital has studied a variety of issues. Gale (2003, 2004) and Gale and Özgür (2005) consider the risk sharing function of bank capital and the

implications for regulation. They show that less risk averse equity holders share risk with more risk averse depositors. In contrast, in our model agents are risk neutral so risk sharing plays no role in determining banks' capital holdings.

Diamond and Rajan (2000) have considered the interaction between the role of capital as a buffer against shocks to asset values and banks' role in the creation of liquidity. Closer to our work, Holmstrom and Tirole (1997) study the role of capital in determining banks' lending capacities and providing incentives to monitor. Other studies such as Hellmann et al. (2000), Repullo (2004) and Morrison and White (2005) analyze the role of capital in reducing risk-taking. In contrast to these papers, our approach focuses on the relationship between unconstrained markets and regulatory requirements and studies the circumstances under which the market equilibrium is constrained efficient and the nature of capital regulation when it is not.

A possible explanation for excess capital based on dynamic considerations is suggested by Blum and Hellwig (1995), Bolton and Freixas (2006), Peura and Keppo (2006), and Van den Heuvel (2008). Banks choose a buffer above the regulatory requirement as a way to ensure they do not violate the regulatory constraint. In these models banks' capital holdings would still be altered by regulatory changes, something not often observed in the data. Our model provides in a static framework an explanation for why capital holdings may be significantly above regulatory requirements and may not be driven by regulatory changes.

In our model, using capital commits the bank to monitor. With no deposit insurance, this allows the bank to raise deposits more cheaply as depositors' confidence that they will be repaid increases. On the lending side, the increased commitment to monitor makes a bank with a large amount of capital more attractive to borrowers and thus improves its "product market" opportunities. From this perspective, the use of capital in our model is reminiscent of the literature on the interaction between capital structure and product market competition, where debt has been identified as having a strategic role in committing the firm to take actions it might not otherwise find optimal (see, e.g., Brander and Lewis (1986), Maksimovic (1988), and Maksimovic and Titman (1991)).

Section 2 outlines the model. Section 3 considers banks' choice of monitoring taking the loan rates and capital amounts as given. The case where there is no deposit insurance is

analyzed in Section 4, while the case with deposit insurance is investigated in Section 5. Section 6 extends the analysis in various directions. Section 7 contains concluding remarks.

2 Model

Consider a simple one-period economy with firms and banks. The firms have access to a risky investment project and need external funds to finance it. The banks lend to the firms and monitor them. For ease of exposition, we assume throughout that each bank lends to one firm.

Each firm's investment project requires 1 unit of funds and yields a total payoff of R when successful and 0 when not. The firm raises the funds needed through a bank loan in exchange for a promised total repayment r_L.

The bank finances itself with an amount of capital k at a total cost $r_E \geq 1$ per unit, and an amount of deposits $1-k$ at a total per unit (normalized) opportunity cost of 1. The bank promises r_D to depositors. The deposit market is perfectly competitive so that the bank will always set r_D at the level required for depositors to recover their opportunity cost of funds of 1 and be willing to participate. In the case with no deposit insurance the bank pays r_D when its loans are repaid, and it pays 0 to depositors the rest of the time. In the case of deposit insurance, depositors are always repaid either by the bank or by the deposit insurance fund so that $r_D = 1$. The assumption that $r_E \geq 1$ captures the idea that bank capital is a more expensive form of financing than deposits, as is typically assumed in the literature.[2]

The function of banks in the economy is to provide monitoring and thus increase the success probability of firms. Specifically, the bank chooses an unobservable monitoring effort q that for simplicity represents the success probability of the firm it finances. Monitoring carries a cost of $q^2/2$ for the bank. Our modelling of bank monitoring captures the idea that firms and banks have complementary skills, so that banks can help firms increase their expected value. Entrepreneurs have an expertise in running the firm. This consists of

[2]See Berger et al. (1995) for a discussion of this issue; and Gorton and Winton (2003), Hellmann et al. (2000) and Repullo (2004) for a similar assumption. Mehran and Thakor (2006) provide a theoretical and empirical analysis of the nature and magnitude of the cost of equity capital.

operating the plant, managing the employees, and so forth. Banks provide complementary financial expertise and can thus help firms increase their expected value.[3]

This framework leads to a partial equilibrium analysis focusing on a single bank where the amount of capital k, the loan rate r_L, and the deposit rate r_D are determined endogenously. The deposit market is always competitive and the determination of r_D depends on the presence of deposit insurance. The determination of k and r_L depends on the presence of a regulator and on the structure of the loan market. All the variables other than q are publicly observable. We consider two cases: in the first one, which we call the "market case," both k and r_L are determined by the bank, while in the other one, defined as the "regulatory case," k is determined by a regulator who maximizes social welfare and r_L is still set by the bank. In either case the solution depends on the allocation of surplus in the credit market. We analyze the two extreme situations where the bank acts as a monopolist or operates in a perfectly competitive system. We discuss the intermediate case in Section 6.

The timing of the model is as follows. In the market case, the bank first selects the level of capital k and then sets the deposit rate r_D and the loan rate r_L. The firm chooses whether to take the loan and invest in the risky project. Then the bank chooses the monitoring effort q. The regulatory case works similarly with the only difference that the regulator chooses the level of capital k initially and then the bank sets r_D and r_L. Once chosen, k, r_D, and r_L are observable to all agents. Figure 1 summarizes the timing of the model.

3 Equilibrium Bank Monitoring

We solve the model by backward induction, and begin with the bank's optimal choice of monitoring for a given amount of capital k, deposit rate r_D, and loan rate r_L. The bank chooses its monitoring effort so as to maximize expected profits as given by

$$\max_q \ \Pi = q(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2. \tag{1}$$

[3]See, e.g., Carletti (2004) and Dell'Ariccia and Marquez (2006), for studies with related monitoring technologies. This is also consistent with the idea of relationship lending in Boot and Thakor (2000). Note, however, that this framework differs from others like Holmstrom and Tirole (1997) in that the borrower does not make any effort choice. We discuss this alternative framework in Section 6.

The first term, $q(r_L - (1-k)r_D)$, represents the expected return to the bank obtained only when the project succeeds net of the repayment to depositors. The second term, kr_E, is the opportunity cost of providing k units of capital, and the last term is the cost of monitoring.

The solution to this problem yields

$$q^* = \min\{r_L - (1-k)r_D, 1\} \tag{2}$$

as the optimal level of monitoring for each bank. Note that, when $q^* < 1$, bank monitoring effort is increasing in the loan rate r_L as well as in the level of capital k the bank holds, but it decreases in the deposit rate r_D. Thus loan rates and capital are two alternative ways to improve banks' monitoring incentives.

This framework implies a moral hazard problem in the choice of monitoring when the bank raises a positive amount of deposits. Since monitoring is unobservable, it cannot be determined contractually. Given it is costly to monitor, the bank has a tendency not to monitor properly unless it is provided with incentives to do so.

4 No Deposit Insurance

We now turn to the determination of the amount of capital k, the loan rate r_L, and the deposit rate r_D. We start by analyzing the case where there is no deposit insurance. In this case, the promised repayment must compensate depositors for the risk they face when placing their money in banks that may not repay. This introduces a liability-side disciplining force on bank behavior since banks have to bear the cost of their risk-taking through a higher promised deposit rate. The expected value of the promised payment r_D must be at least equal to depositors' opportunity cost of 1. Given the level of capital k and the loan rate r_L, depositors conjecture a level of monitoring for the bank, q, and set the deposit rate to meet their opportunity cost. This implies that $qr_D = 1$, or that

$$r_D = \frac{1}{q}. \tag{3}$$

The deposit rate in (3) holds irrespective of the market structure in the loan market and the presence of a regulator. By contrast, the determination of k and r_L depends on both

of these two elements. We consider first the case where the bank acts as a monopolist in the credit market, and then the case where it operates competitively. For either market structure, we start with the "market" solution in the absence of regulation and we then turn to the "regulatory" solution in which a regulator sets the level of capital.

4.1 Monopoly

We begin with the market solution in the case of monopoly banking where the bank sets both k and r_L. The bank's maximization problem is given by:

$$\max_{k,r_L,r_D} \Pi = q(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2 \tag{4}$$

subject to

$$q = \min\{r_L - (1-k)r_D, 1\}, \tag{5}$$

$$qr_D = 1, \tag{6}$$

$$\Pi = q(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2 \geq 0, \tag{7}$$

$$BS = q(R - r_L) \geq 0, \tag{8}$$

$$0 \leq k \leq 1. \tag{9}$$

The bank chooses k, r_L, and r_D so to maximize its expected profit subject to a number of constraints. The first constraint is the monitoring effort chosen by the bank in the final stage after lending is determined. The second constraint is the depositors' participation constraint discussed above, which holds with equality given that the deposit market is competitive. The third and fourth constraints are the bank's and the borrowers' participation constraints, respectively. Note that the borrowers' participation constraint boils down to $r_L \leq R$ if $q > 0$. The last constraint is simply a physical constraint on the level of capital.

The solution to this maximization problem yields the following result.

Proposition 1 *In the case of monopoly banking and no deposit insurance, the market equilibrium is as follows:*

A. For $R \geq 2, k^M = 0, r_L = R, r_D = 1, q = 1, BS = 0,$ *and* $\Pi = SW = R - \frac{3}{2}$*;*

B. For $2 - \frac{1}{2r_E} \leq R < 2, k^M = 2 - R > 0, r_L = R, r_D = 1, q = 1, BS = 0$, *and* $\Pi = SW = \frac{1}{2} - (2 - R)r_E$;

C. For $R < 2 - \frac{1}{2r_E}$, *there is no intermediation.*

Proof: See the appendix. □

The three regions in the proposition are shown in Figure 2. The intuition for the result is as follows. Since the bank has monopoly power, it extracts as much surplus as possible from the borrowers by always setting $r_L = R$. Given that capital is costly, the bank prefers to economize on its use and to derive incentives from the loan rate. In Region A where $R \geq 2$, r_L is sufficiently high to ensure full monitoring even with no capital so $k^M = 0$. The fact that the bank monitors fully ensures that depositors recover their opportunity cost and $r_D = 1$. In Region B, $r_L = R$ is not sufficiently high to provide incentives for full monitoring in the absence of capital. Monitoring is, however, profitable and the bank finds it optimal to keep a positive amount of capital to obtain $q = 1$ and maintain $r_D = 1$. If R falls too low, then the bank's profits become negative and there is no intermediation.

One interesting question is whether introducing capital regulation can improve social welfare in this case. The regulator sets the amount of capital k in order to maximize social welfare but takes the loan rate r_L as set by the market. Here again the bank sets $r_L = R$, borrowers do not have any surplus and social welfare, defined as $SW = \Pi + BS$, just equals Π. This implies that in this case the regulator has the same objective function and thus chooses the same allocation as the market. We then have the following immediate result.

Proposition 2 *In the case of monopoly banking and no deposit insurance, the regulator chooses the same amount of capital as in the market solution,* $k^{reg} = k^M$. *The market is constrained efficient.*

Capital regulation has no role to play in the case of monopoly banking if deposits are not insured. The bank reaps all the surplus from its monitoring effort since it sets $r_L = R$, and it internalizes the cost of its failure through the deposit rate r_D. The liability-side discipline exerted by depositors induces banks to keep a positive amount of capital when it is needed, and this leaves no scope for capital regulation to improve welfare.

4.2 Perfect competition

We now turn to the determination of k, r_L, and r_D in the case of perfectly competitive credit markets. Given the level of monitoring (2) and the depositors' participation constraint (3), banks will have to set competitive contract terms in order to attract borrowers. The market solution solves the following problem:

$$\max_{k,r_L,r_D} BS = q(R - r_L) \tag{10}$$

subject to (5)-(9) as before. The maximization problem differs from the monopoly case only in that the contract now maximizes borrower surplus instead of the bank's profits. The constraints are the same as before. We obtain the following.

Proposition 3 *In the case of competitive banking and no deposit insurance, the market equilibrium is as follows:*

A. For $R \geq 2 - \frac{1}{2r_E}$, $k^{BS} = \frac{1}{2r_E}$, $r_L = 2 - \frac{1}{2r_E}$, $r_D = 1$, $q = 1$, $BS = SW = R - (2 - \frac{1}{2r_E})$ *and* $\Pi = 0$*;*

B. For $R < 2 - \frac{1}{2r_E}$, *there is no intermediation.*

Proof: See the appendix. □

The results in Proposition 3 highlight how competition in the credit market affects the use of bank capital. Similarly to the monopoly case, it is desirable to have the banks fully monitor the firms so that $q = 1$ when projects are sufficiently profitable that there is intermediation ($R > 2 - \frac{1}{2r_E}$). However, banks now derive incentives from a different combination of loan rate and capital relative to the monopoly case. In particular, the loan rate is lower and capital is higher relative to Proposition 1. The reason is straightforward. As already mentioned, capital and loan rates are substitute ways to provide the bank with incentives to monitor. These two instruments differ, however, in terms of their costs and effects on borrower surplus and bank profits. Borrowers prefer banks to hold high levels of capital as a way to commit to high levels of monitoring. By contrast, since capital is a costly input (i.e., $r_E \geq 1$), the bank would prefer to minimize its use and rather receive incentives through a higher loan rate. While increasing r_L is good for incentive purposes,

its direct effect is to reduce the surplus to the borrowers. Given that with competition the contract maximizes borrower surplus, the equilibrium when there is intermediation entails the maximum level of capital and the lowest level of loan rate consistent with $q = 1$ and the banks' participation constraint. In this sense, market discipline can be imposed from the asset side as both the loan rate and bank's capital are used to provide banks with monitoring incentives.[4] In equilibrium, k decreases with the cost of capital r_E while the loan rate r_L increases with r_E. This result implies a negative correlation between capital and the loan rate as a function of the cost of capital in the case of competition.

We next turn to analyze the optimal choice of capital when a regulator sets it to maximize social welfare and the loan rate is still determined as part of a market solution that maximizes the surplus of borrowers. Formally, a regulator solves the following problem:

$$\max_k SW = \Pi + BS = q(R - (1-k)r_D) - kr_E - \frac{1}{2}q^2 \tag{11}$$

subject to the usual constraints (5)-(7) and (9), and

$$r_L = \arg\max_r BS = q(R - r) \geq 0. \tag{12}$$

The regulatory problem differs from the market problem in the objective function, which is now social welfare rather then just borrower surplus. The constraints have the usual meaning, with constraint (12) indicating that the loan rate is still set in the market to maximize borrowers' surplus. The solution to (11) is given below.

Proposition 4 *In the case of competitive banking and no deposit insurance, the regulatory equilibrium is as follows:*

A.1. For $R \geq 2$, $k^{reg} = 0$, $r_L = 2$, $r_D = 1$, $q = 1$, $BS = R - 2$, $\Pi = \frac{1}{2}$, $SW = R - \frac{3}{2}$;

A.2. For $R_{AB} \leq R < 2$, $k^{reg} = 1 - \frac{R^2}{4} > 0$, $r_L = R$, $r_D = \frac{2}{R}$, $q = \frac{R}{2}$, $BS = 0$, *and* $\Pi = SW = \frac{R^2}{8} - (1 - \frac{R^2}{4})r_E$, *where* $R_{AB} = \frac{4r_E + 2\sqrt{r_E + 2r_E^2 - 6r_E^3 + 4r_E^4}}{r_E + 2r_E^2}$;

[4] A related issue is studied in Chemmanur and Fulghieri (1994), who analyze how banks can develop a reputation for committing to devote resources to evaluating firms in financial distress and thus make the correct renegotiation versus liquidation decisions. Borrowers who anticipate running into difficulties may therefore prefer to borrow from banks with a reputation for flexibility in dealing with firms in financial distress. Reputation thus serves as a commitment device for banks similarly to capital in our model.

B. For $2 - \frac{1}{2r_E} \leq R < R_{AB}$, $k^{reg} = \frac{1}{2r_E} > 0$, $r_L = 2 - \frac{1}{2r_E}$, $r_D = 1$, $q = 1$, $BS = SW = R - (2 - \frac{1}{2r_E})$, *and* $\Pi = 0$*;*

C. For $R < 2 - \frac{1}{2r_E}$, *there is no intermediation.*

Proof: See the appendix. □

The proposition is illustrated in Figure 3. The regulatory solution is quite different from that in the monopoly case. In the latter, the loan rate is set to maximize the bank's profit, which coincides with social welfare. Here the regulator can only choose k^{reg} but has to take the loan rate r_L as determined in the market, where it is set to maximize borrower surplus. Given this, the equilibrium loan rate will often not coincide with the loan rate that maximizes social welfare, as borrowers prefer a loan rate that allocates them a greater fraction of the surplus than is socially optimal. Specifically, even though the regulator would prefer to use the loan rate to provide banks with incentives - it is a transfer that does not affect directly the level of social welfare - in its choice of k^{reg} the regulator has to take into account how the market solution for r_L affects banks' incentives to monitor. This can imply a different regulatory level of capital than with monopoly.

In Region A.1 of Proposition 4, projects are so profitable that the equilibrium loan rate $r_L = 2$ is sufficient to provide banks with incentives to fully monitor even if they hold no capital. The regulator therefore sets $k^{reg} = 0$, the loan rate is set just equal to the level that guarantees $q = 1$, and both banks and borrowers earn positive returns.

As the project return R falls below 2, the loan rate by itself is no longer enough to support full monitoring ($q = 1$) without capital. The regulator then has a choice between (a) keeping the capital requirement low and r_L as high as possible, but recognizing that monitoring will be reduced; or (b) requiring that banks hold more capital so as to maintain complete monitoring. In the first case the regulator sets the level of capital such that the market maximizes borrower surplus by setting r_L equal to R. Any lower level of r_L leads to a subsequent level of monitoring by the bank that is insufficient to ensure depositors receive their opportunity cost; depositors will then not lend. Any higher level of r_L violates the borrowers' participation constraint. This solution is optimal in Region A.2.

In the second case the regulator uses a high level of capital to ensure that banks have the correct incentives to monitor. The market then lowers r_L so that borrower surplus is made as large as possible. The limit to this process is set by the participation constraint of the banks. In equilibrium r_L is set so that the banks earn zero profits and borrowers capture the entire surplus. This solution is optimal in Region B. The boundary $R = R_{AB}$ is where the two types of solution give the same level of social welfare. Finally, as before, as the project return falls below $R = 2 - \frac{1}{2r_E}$, we enter Region C where there is no intermediation.

Comparing Proposition 4 with Proposition 1 it can be seen that the regulatory solution with competition is the same as the monopoly solution for $R \geq 2$ except for the loan rate, which is now just enough to reach full monitoring. For $R < 2$ the comparison depends on the region on which one focuses. In Region A.2 of Proposition 4, less capital is mandated by the regulator with perfect competition than is used with monopoly since $1 - \frac{R^2}{4} = \frac{2+R}{4}(2 - R) < 2 - R$. Monitoring is lower as a result and it can be shown using $R > 2 - \frac{1}{2r_E}$ that social welfare is also strictly lower. In Region B of Proposition 4 more capital is mandated by the regulator with perfect competition than with monopoly because in this region $\frac{1}{2r_E} > 2 - R$. Since $q = 1$ in both cases it follows that social welfare is again lower with regulated perfect competition than with monopoly. In the context of our model at least, a monopolistic market structure is preferable to a competitive one. The intuition is that since banks provide a socially valuable, but costly, function, they will provide a suboptimal amount of monitoring unless properly compensated.

We now turn to the comparison between the market solution and the regulatory solution in the case of a competitive credit market. We have the following immediate result.

Proposition 5 *In the case of competitive banking and no deposit insurance:*

A. For $R \geq R_{AB}$ the market solution entails a higher level of capital than the regulatory solution, $k^{BS} > k^{reg}$;

B. For $2 - \frac{1}{2r_E} \leq R < R_{AB}$, the market and the regulatory solutions entail the same level of capital, $k^{BS} = k^{reg}$.

Figure 3 illustrates the proposition (note that Region A comprises A.1 and A.2 from Proposition 4). The results show that in the case of competitive banking the market solution

is inefficient as it induces banks to hold inefficiently high levels of capital when the return of the project is sufficiently high. The basic intuition is that whereas the regulator prefers to economize on the use of costly capital and provide incentives through the loan rate, the market prefers to use capital as long as this is consistent with banks' participation constraint. This implies that banks always break even in the market solution ($\Pi = 0$), while they make positive profits in the regulatory solution in Regions A.1 and A.2 of Proposition 4. As the project return falls below R_{AB} and banks break even in the regulatory solution, the market solution coincides with the regulatory one and the market equilibrium is constrained efficient.

To sum up, the common argument made in the literature is that if capital is relatively costly then banks will minimize its use. This leads to a moral hazard because banks are undercapitalized. Capital regulation is required to ensure that banks do not take excessive risk. In this section we have analyzed a simple model of bank moral hazard and shown that the conventional wisdom does not hold. When there is monopoly power the market allocation is efficient and no regulation is necessary. With perfect competition there is a market failure. However, the problem is that banks use too much capital despite it being a costly form of finance. The nature of the regulation that is necessary to stop this market failure (if it is feasible) is to impose a maximum amount of capital that banks can use. We next turn to the case where there is deposit insurance to see how this alters the analysis.

5 Deposit Insurance

The standard argument in the context of deposit insurance is that it makes funds more easily available to banks and this accentuates banks' moral hazard problem. Capital regulation is then required to offset the increased moral hazard problem. The purpose of this section is to investigate this argument in the context of our model. As before we distinguish the cases of monopoly and competitive banking. In both instances we focus on how much capital is used in the market versus the regulatory solution. In Subsection 5.3 we analyze the effects of deposit insurance compared to the scenarios with no deposit insurance.

5.1 Monopoly

We start by characterizing the market solution under monopoly banking. As before, the bank chooses both k and r_L to maximize its expected profits, taking into account its subsequent monitoring choice and the fact that the firm accepts the loan only if it has a non-negative surplus. In contrast to the previous section, the government now guarantees the deposits of savers: if the bank goes bankrupt the government pays the depositors. We assume the cost of this deposit insurance is paid from revenues raised by non-distortionary lump sum taxes. The amount that banks promise to pay depositors is therefore just $r_D = 1$.

The monopoly bank's profit-maximizing contract now solves the following problem:

$$\max_{k,r_L} \Pi = q(r_L - (1-k)) - kr_E - \frac{1}{2}q^2 \tag{13}$$

subject to (5) and (7) with $r_D = 1$, (8) and (9). The problem is the same as in the case without deposit insurance in Section 4.1 with the only difference that now r_D is simply equal to one and therefore no longer appears as a constraint.

The solution to this maximization problem yields the following result.

Proposition 6 *In the case of monopoly banking with deposit insurance, the market equilibrium always entails $k^M = 0$, $r_L = R$, and $BS = 0$. The rest is as follows:*

A. For $R \geq 2$, $q = 1$ and $\Pi = SW = R - \frac{3}{2}$;

B. For $1 \leq R < 2$, $q = R - 1$ and $\Pi = \frac{(R-1)^2}{2}$. Then, $SW = \frac{R^2}{2} - \frac{3}{2} \gtreqless 0$ for $R \gtreqless \sqrt{3}$.

Proof: See the appendix. □

As in the case without deposit insurance, the bank retains all the surplus from the investment project by setting $r_L = R$ and the firm is indifferent between taking the loan and not. However, unlike the case without deposit insurance, here the bank never holds any capital. The presence of deposit insurance worsens the bank's incentive problem as it magnifies the limited liability problem: the bank does not fully internalize the cost of failure since it pays depositors only when its loans succeed. The deposit rate is now independent of the level of bank monitoring and thus the bank no longer finds it worthwhile to use capital to commit to monitor. The level of r_L is sufficient to ensure full monitoring in Region A,

while in Region B, when project returns are lower, full monitoring is no longer optimal and q falls below one.

Finally, it is interesting to note that with deposit insurance intermediation is always feasible but that for $R < \sqrt{3}$ social welfare is negative. The bank would like to lend because its profits are positive but this is because it does not bear the cost of deposit insurance. There would be no intermediation in this region (for $R < \sqrt{3}$) if the institution insuring depositors refused to provide the insurance.

Given that the bank minimizes its holding of capital when there is deposit insurance, capital regulation now has the potential to improve efficiency and increase social surplus. Because of deposit insurance, the bank chooses the level of capital so as to maximize its expected profits and does not fully internalize the cost of its failure. By contrast, a regulator interested in maximizing social welfare considers the cost borne by the deposit insurance fund in case of bank default and solves the following problem:

$$\begin{aligned} \max_k \ SW &= \Pi + BS - (1-q)(1-k) \\ &= qR - (1-k) - kr_E - \frac{1}{2}q^2 \end{aligned} \tag{14}$$

subject to (5), (8), (9) and

$$r_L = \arg\max_r \Pi(r) \geq 0, \tag{15}$$

with $r_D = 1$. The optimization problem is similar to before. The regulator chooses k to maximize social welfare taking the loan rate as set by the market. Solving the maximization problem above leads to the following result.

Proposition 7 *In the case of monopoly banking with deposit insurance, the regulatory equilibrium always entails $r_L = R$ and $BS = 0$. The rest is as follows:*

A. For $R \geq 2$, $k^{reg} = 0$, $q = 1$ and $\Pi = SW = R - \frac{3}{2}$;

B. For $max\{r_E, R_{BE}\} < R < 2$, $k^{reg} = 2 - R$, $q = 1$ and $\Pi = SW = \frac{1}{2} - (2-R)r_E$, where $R_{BE} = 2 - \frac{1}{2r_E}$;

C. For $R_{CE} < R < r_E < 2$, $k^{reg} = 2 - r_E$, $q = 1 - (r_E - R)$, $\Pi = \frac{1}{2}[1 - (r_E - R)]^2 - (2 - r_E)r_E$, and $SW = \Pi - (r_E - R)$, where $R_{CE} = r_E - 2 + \sqrt{3 + 4r_E - 2r_E^2}$;

D. For $\sqrt{3} < R < 2$ and $r_E \geq 2$, $k^{reg} = 0$, $q = R - 1$, $\Pi = \frac{1}{2}(R-1)^2$, and $SW = \frac{1}{2}R^2 - \frac{3}{2}$;

E. For $R < R_{BE}$, $R < R_{CE}$, $R < \sqrt{3}$, as shown in Figure 4, $SW < 0$ and there is no intermediation.

Proof: See the appendix. □

The most important insight of the proposition is that welfare maximization may require a positive level of capital. This occurs when raising capital has an incentive effect in that it increases the monitoring effort of the bank (i.e., when $R < 2$) and when the positive incentive effect on social welfare of raising capital outweighs the cost r_E (i.e., when $r_E < 2$). Capital regulation is therefore a second best solution to the distortion of deposit insurance. When deposits are fully insured, banks can reduce monitoring without having to pay more to depositors. Banks are thus more likely to default, with the deposit insurance fund left to make up the difference. By forcing banks to hold a positive amount of capital, regulation improves banks' monitoring incentives and reduces the disbursement of the deposit insurance fund, as in, for example, Hellmann et al. (2000), Repullo (2004) and Morrison and White (2005).

It is interesting to note that, as in the case without deposit insurance, there is now again a region where there is no intermediation. Since the regulator's objective is to maximize social welfare, the regulator prefers to prevent intermediation from occuring whenever SW is negative as in Region E. One way that the regulator could do this would be to eliminate the provision of deposit insurance. Another would be to set k^{reg} sufficiently high that banks' participation constraint is violated.

Comparing Propositions 6 and 7 leads to the following immediate result.

Proposition 8 *In the case of monopoly banking and deposit insurance, capital regulation requires that banks hold a higher amount of capital than in the market solution, $k^{reg} > k^M$, in Regions B and C as defined in Proposition 7. Outside of these regions $k^{reg} = k^M$ and the market is constrained efficient.*

This result is illustrated in Figure 4. It establishes that in our framework a regulator may require a higher amount of capital than the amount that maximizes the bank's profits. When this happens regulation is beneficial as it increases social welfare relative to what

would be obtained under the market solution. In these instances, there is a rationale for capital regulation as a way of providing the bank with incentives to monitor. This is entirely due to the presence of deposit insurance which allows the bank to take advantage of the implicit subsidy provided by regulation. This case corresponds to the conventional wisdom discussed earlier that the distortion imposed by deposit insurance requires capital regulation to correct it. Notice that this only holds for low r_E and R. For other values the market is constrained efficient.

5.2 Perfect competition

We start by considering how a perfectly competitive market operates when there is deposit insurance and no capital regulation. The market sets k and r_L to maximize borrower surplus subject to the usual constraints, again assuming that $r_D = 1$. Solving this problem gives the following result.

Proposition 9 *In the case of competitive banking with deposit insurance, in the market equilibrium it always holds that* $r_L < R$ *so* $BS > 0$, *and* $\Pi = 0$. *The level of capital, loan rate and monitoring are as follows:*

A. For $R \geq R_{AB}$, $k^{BS} = \frac{1}{2r_E}$, $r_L = 2 - k^{BS}$, $q = 1$ *and* $BS = SW = R - (2 - \frac{1}{2r_E})$;

B. For $R < R_{AB}$, $k^{BS} = \left(\frac{\sqrt{2r_E} - \sqrt{2r_E - 3(R-1)}}{3}\right)^2 < \frac{1}{2r_E}$, $r_L = 1 - k^{BS} + \sqrt{2r_E k^{BS}}$, $q = \sqrt{2r_E k^{BS}} < 1$, $BS = q(R - 1 + k^{BS} - q)$ *and* $SW = qR - q^2 - (1 - k^{BS}) \gtreqless 0$ *for* $R \gtreqless \min\{R_{AB}, \widehat{R}\}$, *where* $\widehat{R}$ *solves* $SW(\widehat{R}) = q\widehat{R} - q^2 - (1 - k^{BS}) = 0$.

The boundary R_{AB} *is defined as* $R_{AB} = \frac{3}{2} - \frac{3}{8r_E} + \frac{r_E}{2}$ *for* $r_E < \frac{3}{2}$ *and* $R_{AB} = 3 - \frac{3}{2r_E}$ *for* $r_E \geq \frac{3}{2}$.

Proof: See the appendix. □

The results in Proposition 9 highlight again the incentive mechanisms for bank monitoring that are used in a competitive credit market. As already mentioned, capital and loan rates are substitute ways to provide banks with monitoring incentives. Borrowers prefer that banks charge lower interest rates and hold large amounts of capital, whereas banks prefer to minimize the use of capital and receive incentives through a higher loan rate. Given that the

market solution maximizes borrower surplus, the equilibrium involves the maximum amount of capital consistent with banks' participation constraint and provides a loan rate up to the point where the (marginal) positive incentive effect of a higher loan rate equals its negative direct effect on borrower surplus. Thus, in addition to capital, the loan rate is still used to provide monitoring incentives - and thus market discipline - from the asset side. However, the market solution may now entail a lower level of monitoring relative to the case without deposit insurance.

The proposition is illustrated in Figure 5. In both regions the zero-profit constraint for banks binds. If it did not it would always be possible to increase BS by lowering r_L and increasing k while holding q constant. The exact amounts of monitoring and capital in equilibrium depend on the return R of investment projects and on the cost of capital r_E. In Region A project returns are high and it is worth setting a high r_L and k to ensure full monitoring. With the lower returns in Region B, both r_L and k are reduced and $q < 1$. One interesting feature of the equilibrium is that, much like in the previous subsection (and differently from the case without deposit insurance), there is always lending because of deposit insurance. Deposits can always be raised at $r_D = 1$ and since they only have to be repaid by the bank when its loans pay off, it is always possible to create positive borrower surplus and satisfy the zero profit constraint. As in the monopoly case, $SW < 0$ for low enough R because of the cost of repaying depositors when the bank fails.

Following the same structure as before, we now turn to analyze the optimal choice of capital from a social welfare perspective when there is competition and loan rates are set as part of a market solution to maximize the return to borrowers. The solution to this gives the following result.

Proposition 10 *In the case of competitive banking with deposit insurance, the regulatory equilibrium is as follows:*

A. $k^{reg} = 0$, $r_L = \frac{R+1}{2}$, $q = 1$, $BS > 0$, $\Pi > 0$, *and* $SW > 0$;

B. $k^{reg} = 3 - R$, $r_L = R - 1$, $q = 1$, $BS > 0$, $\Pi > 0$, *and* $SW > 0$;

C. $k^{reg} = R + 1 - 4(r_E - 1)$, $r_L = 2(r_E - 1)$, $q = R - 2(r_E - 1) < 1$, $BS > 0$, $\Pi > 0$, *and* $SW > 0$;

D. $k^{reg} = 0$, $r_L = \frac{R}{2}$, $q = \frac{R-1}{2} < 1$, $BS > 0$, $\Pi > 0$, *and* $SW > 0$;

E. $k^{reg} = \frac{1}{2r_E}$, $r_L = 2 - \frac{1}{2r_E}$, $q = 1$, $BS = SW > 0$, $\Pi = 0$;

F. There is no intermediation because $SW < 0$.

The boundaries defining regions A through F are shown in Figure 6 and, together with the expressions for BS, Π, *and* SW, *are defined in the appendix.*

Proof: See the appendix. □

The proposition is illustrated in Figure 6. As usual, both capital and the loan rate are used to provide monitoring incentives, and their exact amounts depend on the return of the project R and the cost of equity r_E. In Region A, R is sufficiently large that it is possible for the regulator to set $k^{reg} = 0$ and still have full monitoring, with incentives being provided by the loan rate r_L. Both profits and borrower surplus are positive in this region. For lower R, in Region B, borrowers prefer to reduce r_L, thus providing lower incentives through the interest rate. Since r_E is relatively low, the remaining incentives to monitor are provided by the use of capital, k^{reg}. In Region C, the regulator uses less capital since r_E is higher, and it is no longer optimal to provide full incentives to monitor, so that $q < 1$. In Region D capital is too expensive to be worth using to provide incentives to monitor and imperfect incentives are provided through r_L alone. In Region E the regulator uses capital to make up for low incentives provided by a low value of r_L. In Region F there is no intermediation since $SW < 0$. As in Proposition 7, this is achieved by not providing deposit insurance or by setting k^{reg} sufficiently high to violate banks' participation constraint.

We next compare the market and regulatory solutions. The comparison between the values of k^{BS} and k^{reg} leads to the following result.

Proposition 11 *With competition and deposit insurance the comparison between the market and the regulatory solutions is as follows:*

A. $k^{BS} > k^{reg}$;

B. $k^{BS} = k^{reg}$;

C. $k^{BS} < k^{reg}$.

D. No intermediation with regulation.

The boundaries defining regions A-C are shown in Figure 7 and are defined in the appendix.

Proof: See the appendix. □

For the case studied in Section 4.2, with competition and no deposit insurance, the market solution is either constrained efficient or uses too much capital. It can be seen from Proposition 11 and Figure 7 that both of these cases still arise with deposit insurance. The competitive solution uses too much capital in Region A where R is high. As before, the reason is that in the competitive solution borrowers are always better off with lower r_L and higher capital as long as this is consistent with banks' participation constraint. The regulator, on the other hand, prefers to use a lower level of capital and provide incentives through a higher interest rate. In Region B the market solution is constrained efficient. Only in the relatively small area denoted as Region C does both intermediation occur and optimal regulation require a level of capital above the market solution. Thus the main conclusion of Section 4 remains valid even when there is deposit insurance. The basic tendency with competition is for there to be too much capital used in the market solution rather than too little.

5.3 The effects of deposit insurance

In this subsection we consider the effect of deposit insurance by comparing the different cases without and with deposit insurance. We start with the effect on monitoring incentives. Without deposit insurance banks have an incentive to fully monitor ($q = 1$) both under monopoly (Proposition 1) and under competition (Proposition 3) as long as there is intermediation. With deposit insurance banks monitor less ($q < 1$) for $R < 2$ in the case of monopoly (Proposition 6) and for $R < R_{AB}$ in the case of competition (Proposition 9). Similar results hold for the regulatory solutions under both monopoly and competition. The reason for the higher monitoring without deposit insurance is that an increase in q lowers r_D so that there is an additional incentive to monitor with the result that $q = 1$ always holds. Such an effect is absent with deposit insurance as the deposit rate is $r_D = 1$ and is independent of the degree of bank monitoring. By failing to reduce the bank's cost of

raising deposits when the probability of bankruptcy decreases, deposit insurance introduces a negative force on bank monitoring.

As a result of this effect of deposit insurance on monitoring, social welfare is usually lower when R is low compared to the case of no deposit insurance. However, this is not always so. In some cases deposit insurance can entail a positive effect on the level of social welfare as it provides a way of guaranteeing payments to depositors without involving the use of costly capital. This occurs when the reduction in the use of costly capital more than outweighs the negative incentive effect of deposit insurance on monitoring incentives. This is illustrated in Figure 8 for the market solutions in the monopoly case without and with deposit insurance as described in Propositions 1 and 6.

Consider the levels of social welfare in these propositions without and with deposit insurance for $R < 2$. Social welfare is at least as high with deposit insurance as without if

$$\frac{R^2}{2} - \frac{3}{2} \geq \frac{1}{2} - (2 - R)r_E,$$

which has the boundary

$$R = 2(r_E - 1).$$

This leads to Region A in Figure 8 where socially valuable intermediation is feasible in both cases but social welfare is higher with deposit insurance than without. The no intermediation boundary in Proposition 1 is $R = 2 - 1/2r_E$ while the one in Proposition 6 is $R = \sqrt{3}$. Thus the case with deposit insurance involves socially valuable intermediation while the case without deposit insurance does not in Region B of Figure 8, where $r_E > \frac{1}{2\left(2-\sqrt{3}\right)}$ and $\sqrt{3} \leq R < 2 - 1/2r_E$.

Similar qualitative results on the role of deposit insurance are obtained in the regulatory solution with monopoly. In contrast, in the case of competition deposit insurance either makes no difference if R is sufficiently high or leads to a reduction in social welfare.

It is also interesting to note that there are fewer parameter values where $k^{BS} > k^{reg}$ in the market solution when there is deposit insurance. This can be easily seen by comparing Propositions 5 and 11. As illustrated in Figure 3, the boundary for $k^{BS} > k^{reg}$ to occur without deposit insurance is always below $R = 2$, while with deposit insurance it is always

above $R = 2$, as shown in Figure 7. Therefore, $k^{BS} > k^{reg}$ occurs for a larger range of parameter values without deposit insurance than with. The reason is again that deposit insurance blunts monitoring incentives and thus more capital must be used in the regulatory equilibrium to provide incentives.

We have assumed that deposit insurance is funded using general revenues raised by non-distortionary lump sum taxes. If distortionary taxes are used then the effective cost of deposit insurance will be higher. Another possibility is to directly charge the banks for deposit insurance. Since the banks have limited liability it will be necessary to cover the cost of deposit insurance when they are solvent. The higher charge for deposit insurance that this leads to will likely also result in a distortion.

6 Extensions

In this section we consider a few important extensions. First, we consider an alternative framework where the borrower exerts effort and monitoring helps alleviate the resulting moral hazard. Second, we consider alternative market structures where both banks and borrowers obtain part of the surplus generated by the investment projects. Third, we analyze the case with a classic asset substitution problem where banks can choose loans with a lower probability of success but with a higher payoff in case of success. This extension can be used to obtain insight on the role of capital in the context of relationship versus transactional lending. Finally, we study the case where banks have a franchise value from continuing to operate, which introduces some simple dynamic considerations.

6.1 The monitoring technology

So far we have assumed that bank monitoring directly determines the probability of success of the investment project. This simplifies the analysis in that the borrower does not exert any effort. Holmstrom and Tirole (1997) use a different framework where bank monitoring reduces borrowers' private benefits. We adapt their approach so that monitoring influences the project success probability only indirectly. Specifically, assume that the firm invests in a project which, as before, yields a total payoff of R when successful and 0 when not. The

probability of success depends now on the effort of the borrower. In particular, the borrower chooses an unobservable effort $e \in [0,1]$ that determines the probability of success of the project and carries a cost of $e^2/2$. The borrower also enjoys a (nonpecuniary) private benefit $(1-e)B > 0$, which is maximized when he exerts no effort. One way of interpreting the cost $-eB$ is that putting in effort reduces the amount of time the borrower can spend pursuing privately beneficial activities, or enjoying the perks of being in charge of the project. Bank monitoring helps alleviate moral hazard in this framework. In particular, the bank chooses a monitoring effort q which reduces the private benefit of the borrower to $(1-e)B(1-q)$ and entails a cost of $q^2/2$. We can think of bank monitoring as taking the form of using accounting and other controls to reduce the borrower's private effort, or to reduce his ability to consume perks. Monitoring is chosen before the borrower's effort.

Given this set up, for given k, r_D, and r_L, the borrower chooses his effort to maximize

$$BS = e(R - r_L) + (1-e)B(1-q) - \frac{1}{2}e^2$$

so that

$$e^* = \min\left\{(R - r_L) - B(1-q), 1\right\}.$$

The bank chooses q to maximize

$$\Pi = e^*(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2$$

which yields

$$q = \min\left\{(r_L - (1-k)r_D)B, 1\right\}.$$

It can be seen that this version of the model works similarly to our basic model. The borrower's effort decreases with the loan rate r_L and the private benefit B while it increases with the project return R and the monitoring effort q. Bank monitoring in turn increases in the loan rate r_L, the level of capital k and the private benefit B. Thus, as before, bank monitoring positively affects the success probability of the project as it reduces borrower's moral hazard. The difference is that, as in Boyd and De Nicolo (2005), in setting the loan rate r_L the bank will now have to consider also the negative effect that this has on the borrower's effort so that in equilibrium its level will be somewhere in between the levels

found in the analysis above in the case of monopoly and perfect competition. This implies also different levels of capital and of monitoring in equilibrium, but it does not affect the qualitative results. In particular, there will again often be a tendency for banks to use too much capital rather than too little.

6.2 Alternative market structures

The analysis above has focused on the extreme cases of monopoly and perfect competition. The key issue is what the contract maximizes. In the monopoly case the contract maximizes the bank's profit and the bank gets the surplus. The high surplus provides banks with incentives to monitor efficiently with no or little capital. At the other extreme, with perfect competition borrower surplus is maximized and capital is used in the market solution to provide incentives for banks to monitor. Because capital is costly, competition can lead to inefficiencies and capital regulation may be needed to limit these inefficiencies. With intermediate market structures surplus is split between banks and borrowers, with each obtaining a positive expected return. The effects identified above will remain in such cases. In particular, the more surplus that banks obtain the less capital they will use. The more surplus borrowers obtain the greater will be the tendency for banks to use capital. This suggests the empirical prediction that the more competitive is the banking sector, the greater the amount of capital that will be used. This prediction is consistent with the result in Schaeck and Cihak (2007) that European banks tend to hold higher capital ratios when operating in a more competitive environment.

6.3 Relationship and transactional lending

We have assumed throughout that banks can only finance projects that benefit from monitoring. In that context, we have shown that capital plays a role as a commitment device for banks to monitor and thus attract borrowers. We now modify this basic framework and, similarly to Boot and Thakor (2000), we consider the case where banks can choose between investing in a project which is identical to the one studied so far, and an alternative project with a fixed success probability p_T of returning a payoff R_T. We will refer to the first kind of loan as a "relationship" loan since it benefits from the interaction with the bank, and the

latter loan as a "transactional" loan. The crucial difference is that bank monitoring affects only the success probability of the relationship loan, given as before by q. As a consequence, the bank's capital holdings will now affect the relative attractiveness of the two projects and capital regulation will play the additional role of affecting the distribution of bank funds across projects.

Assume that $p_T < q(0) < 1$, $R_T > R$, and $p_T R_T < q(0)R$, where $q(k)$ is the level of monitoring for a relationship loan when the bank has capital k. The transactional project has a lower probability of success than a relationship loan even with no capital ($k = 0$), a higher payoff in case of success, but a lower expected payoff. These assumptions introduce the possibility of a classic asset substitution problem. Banks may prefer to make transactional loans even though relationship loans are more valuable socially. Capital regulation can help to correct this market failure.

To analyze the bank's choice in more detail, consider, for example, the case of monopoly banking where banks set the loan rate to obtain all the returns from the projects and have expected profits equal to

$$\Pi_R = q(R - (1-k)r_D) - kr_E - \frac{1}{2}q^2,$$

$$\Pi_T = p_T(R_T - (1-k)r_D) - kr_E,$$

from the relationship and the transactional loans, respectively. We first note that $\frac{\partial \Pi_T}{\partial k} = p_T r_D - r_E < 0$ so that capital decreases the attractiveness of the transactional loan and the bank would not want to hold any capital when investing in this project. This implies that capital regulation has the additional role of affecting the distribution of funds towards socially valuable investment projects. In situations where the asset substitution problem leads to an inefficiency, a minimum capital requirement can be used to rule out transactional lending and ensure relationship lending. Such a requirement will need to be higher the higher are R_T and r_D. Once this capital regulation is in place, the factors considered in the basic model concerning relationship lending will come into play. Capital is further used to provide monitoring incentives, and our main result that capital can be too high relative to the social welfare maximizing level will still hold. In this case optimal regulation will involve both a

maximum and a minimum capital requirement.

Besanko and Kanatas (1996) also consider a model with bank monitoring of loans and an asset substitution problem. In their model there is an agency problem between managers and other shareholders in the bank. Among other things, they show that an increase in capital requirements may lead to increased risk taking. The reason is that raising equity dilutes current managers' stake in the firm and this can reduce managers' incentives to exert effort. In our model there is no agency problem between managers and shareholders. Our results hold for banks where the interests of managers and shareholders are strongly aligned through a range of contractual provisions so that there is no dilution effect. If we were to introduce a similar agency problem, capital could have an additional, negative effect on monitoring incentives and could therefore be used less than in our current framework. In particular, raising capital could penalize banks engaging in relationship lending as it could have a negative effect on the success probability of their loans through a lower monitoring effort.

The considerations developed above also have implications for the penetration of banks into foreign markets and their need for staying power. There has been much discussion in recent years on the difficulties banks face when attempting to expand internationally. Information asymmetries developed through long term relationships, for instance, have been identified as possible barriers to entry, leading entrant banks to focus their entry decisions toward market segments less subject to private information (see Dell'Ariccia and Marquez, 2004, and Marquez, 2002). Clarke et al. (2001) and Martinez-Peria and Mody (2004) provide evidence that this is indeed the case for banks' foreign penetration in Latin American countries. These results point to the need for entrant banks to have a competitive edge particularly in markets where they suffer larger information disadvantages. Bank capital endows banks with just such an advantage in attracting borrowers by providing a channel through which they can commit to monitor. In the context of our model, therefore, we would expect well-capitalized entrant banks to have more "staying power" when entering a market. Well capitalized (entrant) banks should be in a better position to monitor borrowers subject to information problems, and should be most attractive to borrowers that benefit most from this monitoring. To the extent that this staying power is most relevant for

relationship lending - one area identified as being information intensive - we would expect that well-capitalized banks should obtain a disproportionately higher share of relationship loans.

6.4 Bank franchise value

Much discussion of bank behavior has focused on the role of franchise value as a possible way to reduce risk-taking (see, e.g., Keeley, 1990). Franchise value acts as an additional instrument providing a commitment to monitor. The intuition is simply that a greater franchise value means that the bank has a larger incentive to remain viable and in business, which leads it to dedicate more resources to monitor its borrowers so as to increase the success probability of its loans. As a consequence, the optimal level of capital needed to provide monitoring incentives is lower than without franchise value.

We endogenize the franchise value by characterizing the equilibrium of the dynamic model that is just a repeated version of our model. If a bank stays solvent it is able to continue to the next period. If it defaults it goes out of business. Introducing a discount factor of δ and a time index t for each period, the franchise value at date t, denoted by FV_t, is given by the current profits and the discounted value of the franchise value at date $t+1$ so

$$FV_t = \Pi_t + q_t \delta FV_{t+1} = q_t(r_{Lt} - (1-k_t)r_{Dt}) - k_t r_E - \frac{1}{2}q_t^2 + q_t \delta FV_{t+1}.$$

The maximization of FV_t leads to a monitoring effort at time t, q_t, equal to

$$q_t = \min\{r_{Lt} - (1-k_t)r_{Dt} + \delta FV_{t+1}, 1\}.$$

For interior solutions a higher franchise value leads to higher monitoring. Given the problem is the same in each period, the optimal solution must be the same each period and thus $FV_t = FV_{t+1} = FV$. Taking the interior solution for q and eliminating the t indexing, we can then express FV as

$$FV = q(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2 + q\delta FV,$$

from which

$$FV = \frac{1}{1-q\delta}\left(q(r_L - (1-k)r_D) - kr_E - \frac{1}{2}q^2\right) = \frac{1}{1-q\delta}\Pi.$$

From this, it can be seen that the franchise value depends positively on the bank's static profit Π and equals zero whenever $\Pi = 0$. Thus, the role of the franchise value in reducing risk-taking depends crucially on the market structure of the credit market in that bank profits will usually be higher in monopolistic markets than in competitive markets. It may also depend on the presence or absence of regulation since, as shown above, optimal capital regulation may entail setting a capital requirement that provides banks with rents, even when the market is competitive.

7 Concluding Remarks

A standard view of capital regulation is that it offsets the risk-taking incentives provided by deposit insurance. A common approach in the study of bank regulation has been to assume that any capital requirements will be binding, since equity capital is generally believed to be more costly than other forms of finance. However, in many cases banks hold large levels of capital and regulatory requirements appear not to be binding. Moreover, banks' capital holdings seem to have varied substantially over time independently of regulatory changes. In this paper we have developed an alternative view of capital that is consistent with the observation that banks may hold high levels of capital even above the levels required by regulation.

Our approach is based on the idea that both the loan rate charged by the bank and capital provide incentives to monitor. We adopt the standard assumption in the literature that capital is more costly than other sources of funds. In the benchmark case of no deposit insurance, a monopolistic market structure leads to a constrained efficient allocation. With perfect competition the market provides incentives for banks to use too much capital because borrowers prefer lower interest rates and higher capital as they do not bear the cost of the capital. A regulator would want to reduce the amount of capital they use. When there is deposit insurance banks' incentives to monitor are reduced. With a monopolistic market structure banks do not use any capital because they ignore the cost of default to the deposit

insurance fund. A regulator that takes this into account requires banks to use more capital. In the case of competitive markets the basic tendency is for banks to use too much capital as in the case of no deposit insurance. There are relatively few parameter values where banks use too little capital. Deposit insurance usually lowers social welfare but there are some cases where it can improve it.

There are many interesting directions for future research. In our model we assume that all banks are the same and operate in either monopolistic or perfectly competitive markets. Differently, Boot and Marinč (2006) consider heterogeneous banks with a fixed cost of monitoring operating in markets with different degrees of competition. Incorporating these elements into our framework is one of these interesting directions.

We have focused on regulatory capital that maximizes social welfare. A number of other approaches are possible. In many instances it seems that actual regulatory capital levels have been set based on historically observed levels. Basel II represents another type of approach where regulatory capital is derived from the criterion of covering the bank's losses 99.9% of the time. The discrete version of the model we have developed is not appropriate for analyzing this type of criterion. A version with a continuous distribution of returns is necessary. Developing this extension of our model is another interesting topic for future research.

A Proofs

Proof of Proposition 1: Substituting (6) into (5) when $q < 1$ and solving for the equilibrium value of monitoring, we obtain two solutions as given by $q_1 = \frac{1}{2}\left(r_L + \sqrt{r_L^2 - 4(1-k)}\right)$ and $q_2 = \frac{1}{2}\left(r_L - \sqrt{r_L^2 - 4(1-k)}\right)$, with $q_1 > q_2$. The relevant solution is q_1, as it can be shown that both banks and borrowers are better off with the higher level of monitoring. To see this, note that, in equilibrium, bank profits are given by

$$\Pi(q) = q(r_L - (1-k)\frac{1}{q}) - kr_E - \frac{1}{2}q^2 = qr_L - (1-k) - kr_E - \frac{1}{2}q^2, \tag{16}$$

which is strictly increasing in q for $q \leq 1 \leq r_L$. Since $q_2 < q_1 < r_L$, banks prefer the equilibrium with the higher level of monitoring. The equilibrium return for firms is just equal to zero when there is monopoly banking so that firms are indifferent between the two solutions of q. Since also depositors are indifferent between the two levels of monitoring as they just receive their opportunity cost of funds in expectation, the higher level of monitoring, q_1, yields a Pareto-superior equilibrium and is therefore the relevant solution. This implies that

$$q = \min\left\{\frac{1}{2}\left(r_L + \sqrt{r_L^2 - 4(1-k)}\right), 1\right\}. \tag{17}$$

We now turn to the determination of r_L and k. Consider first the case when $q = 1$. Then, $\frac{\partial \Pi}{\partial r_L} = 1$ so that in equilibrium $r_L = R$; and $\frac{\partial \Pi}{\partial k} = (1 - r_E) < 0$ for $r_E > 1$ so that the bank would like to choose k as small as possible given $q = 1$. To see when this holds, we substitute $r_L = R$ in q for $k = 0$ and have $q = \min\{\frac{1}{2}\left(R + \sqrt{R^2 - 4}\right), 1\}$. This implies $q = 1$ for $k = 0$ when $R \geq 2$. Using this in (16) gives $\Pi = R - 3/2$. Since $r_L = R$ implies $BS = 0$, we also have $SW = \Pi$. This gives part A of the proposition.

Consider now the case when $q < 1$. We have

$$\frac{\partial \Pi}{\partial r_L} = q + (r_L - q)\frac{\partial q}{\partial r_L} > 0,$$

since $\frac{\partial q}{\partial r_L} = \frac{1}{2} + \frac{1}{2}r_L(r_L^2 - 4(1-k))^{-\frac{1}{2}} > 0$ given that $r_L^2 - 4(1-k) > 0$ for an equilibrium to exist; and $(r_L - q) > 0$ since $r_L \geq \frac{1}{q} + \frac{k(r_E - 1)}{q} + \frac{1}{2}q > 1$ from the bank's participation constraint that $\Pi \geq 0$. Hence in equilibrium it is again the case that $r_L = R$.

To find the optimal level of k with $q < 1$, we first show that Π is a concave function of k. Substituting q into Π and differentiating with respect to k, we obtain

$$\frac{\partial \Pi}{\partial k} = (R - q)\frac{\partial q}{\partial k} - (r_E - 1), \tag{18}$$

where $\frac{\partial q}{\partial k} = (R^2 - 4(1-k))^{-\frac{1}{2}} > 0$ and

$$\frac{\partial^2 \Pi}{\partial k^2} = -\frac{\partial q}{\partial k} + (R - q)\frac{\partial^2 q}{\partial k^2} < 0$$

since $\frac{\partial q}{\partial k} = (R^2 - 4(1-k))^{-\frac{1}{2}} > 0$ and $\frac{\partial^2 q}{\partial k^2} = -2(R^2 - 4(1-k))^{-\frac{3}{2}} < 0$ for $q < 1$.

We can now find the optimal level of k from the first order condition. Substituting the expressions for q as in (17) and $\frac{\partial q}{\partial k}$ into (18), we have

$$\frac{\partial \Pi}{\partial k} = \frac{R}{2\sqrt{R^2 - 4(1-k)}} - r_E + \frac{1}{2} = 0,$$

from which we obtain

$$k^* = \frac{R^2}{4(1-2r_E)^2} + 1 - \frac{R^2}{4}.$$

For this to be the optimal solution, it has to be consistent with the conditions $q \leq 1$ and $\Pi \geq 0$. Substituting k^* into the expression for q as in (17), we obtain $q = \frac{r_E R}{2r_E - 1}$ so that $q \leq 1$ if $R \leq 2 - \frac{1}{r_E}$. Substituting the expressions for k^* and q into the expression for Π and solving the boundary $\Pi = 0$ for R, we have that $\Pi \geq 0$ if $R \geq 2\sqrt{1 - \frac{1}{2r_E}}$. It is easy to see that these two conditions on R are inconsistent as $2\sqrt{1 - \frac{1}{2r_E}} > 2(1 - \frac{1}{2r_E}) = 2 - \frac{1}{r_E}$. This implies that k^* is not a feasible solution.

To find the optimal, feasible solution for k, we first show that the value of k such that $q = 1$ is smaller than k^* and is consistent with $\Pi \geq 0$. Equating $q = 1$ in the first expression in the brackets in (17) and solving for k, we obtain $k = 2 - R$. Substituting this and $q = 1$ into Π, we get that $\Pi \geq 0$ is satisfied for

$$R \geq 2 - \frac{1}{2r_E}. \tag{19}$$

Now to show that $k = 2 - R < k^*$, note that $2 - \frac{1}{2r_E} > 1 - \frac{1}{2r_E}$, which can be rearranged as

$$\frac{2 - \frac{1}{2r_E}}{2r_E - 1} > 2 - (2 - \frac{1}{2r_E}).$$

Using (19), it follows that

$$\frac{R}{2r_E - 1} > 2 - R \Leftrightarrow \frac{R^2}{4(2r_E - 1)^2} > \frac{1}{4}(2 - R)^2,$$

which can be rearranged as

$$\frac{R^2}{4(2r_E - 1)^2} > (2 - R) - (1 - \frac{R^2}{4})$$

so that $k = 2 - R < k^*$.

Using the fact that Π is concave in k it follows that for the lowest value of k consistent with $q = 1$, given by $k = 2 - R$, the left hand derivative $\frac{\partial \Pi}{\partial k}^- > 0$. Now at this value of k the right hand derivative $\frac{\partial q}{\partial k}^+ = 0$, which implies that $\frac{\partial \Pi}{\partial k}^+ < 0$, so $q = 1$ and $k = 2 - R$ is the

optimal solution. Substituting in (16) gives

$$\Pi = \frac{1}{2} - (2 - R)r_E.$$

Since $BS = 0$ we have $\Pi = SW$. Intermediation will only take place if $\Pi > 0$ or equivalently $R > 2 - 1/2r_E$. Parts B and C of the proposition follow. □

Proof of Proposition 3: As before, the equilibrium value of monitoring q is given by (17). Assuming $q < 1$, we substitute for q in the expression for borrower surplus to obtain $BS = q(R - r_L) = \frac{1}{2}\left(r_L + \sqrt{r_L^2 - 4(1-k)}\right)(R - r_L)$. As before, we need $r_L \geq 2\sqrt{1-k}$ for an equilibrium to exist.

We now turn to the determination of r_L and k. We first show that $\Pi > 0$ is never optimal. We divide this analysis into four cases as a function of the possible equilibrium values of q and k.

Case 1: $q < 1$ and $k < 1$. Given that $BS = q(R - r_L) > 0$, having $\Pi > 0$ cannot be optimal since borrowers would prefer to lower r_L slightly and raise k in such a way as to not reduce q. This increases BS while keeping $\Pi \geq 0$.

Case 2: $q < 1$ and $k = 1$. With $k = 1$, we obtain that $q = r_L \leq 1$. Substituting into the expression for bank profits yields $\Pi = {r_L}^2 - r_E - \frac{1}{2}{r_L}^2 = \frac{1}{2}{r_L}^2 - r_E < 0$ since $r_L \leq 1$, thus violating the bank's participation constraint.

Case 3: $q = 1$ and $k < 1$. Again, borrowers would prefer to lower r_L slightly and increase k. This increases BS and maintains $\Pi \geq 0$.

Case 4: $q = k = 1$. Then $\Pi = r_L - r_E - \frac{1}{2} \geq 0 \Leftrightarrow r_L \geq r_E + \frac{1}{2} > 1$. Note that for $k = 1$ we have $q = \min\{r_L, 1\} = 1$. We therefore want to lower r_L until $r_L = r_E + \frac{1}{2}$, which still leaves $q = 1$ but reduces Π to zero.

These four cases together imply that Π must equal zero at the optimum. Consider now a candidate solution with $q = 1$. From $\Pi = r_L - \frac{3}{2} + k(1 - r_E) = 0$, we obtain $r_L = \frac{3}{2} + k(r_E - 1)$. For this to be optimal for borrowers, k must be the lowest value consistent with $q = 1$. Substituting the expression for r_L into (17) we obtain

$$q = \frac{1}{2}\left(\frac{3}{2} + k(r_E - 1) + \sqrt{\left(\frac{3}{2} + k(r_E - 1)\right)^2 - 4(1-k)}\right).$$

Setting this equal to one and solving for k gives $k = \frac{1}{2r_E}$. With this value for k the expression for r_L gives $r_L = 2 - \frac{1}{2r_E}$. Note that, given our candidate solution has $q = 1$, no other solution can increase BS while satisfying the bank's participation constraint. For $k > \frac{1}{2r_E}$, $r_L > 2 - \frac{1}{2r_E}$, but q does not increase beyond 1, thus lowering BS. For $k < \frac{1}{2r_E}$, satisfying the bank's participation constraint with equality requires reducing r_L. This lowers q to below 1, violating the assumption that $q = 1$ at the optimum. Note further that for $q = 1$, $BS = R - \left(2 - \frac{1}{2r_E}\right)$, which is clearly greater than zero only for $R > 2 - \frac{1}{2r_E}$.

It remains to be shown that at the optimum $q = 1$ must hold. To see this, recall the

expressions for bank monitoring and profits, respectively:

$$\begin{aligned} q &= \frac{1}{2}\left(r_L + \sqrt{r_L^2 - 4(1-k)}\right), \\ \Pi &= qr_L - (1-k) - kr_E - \frac{1}{2}q^2 = 0. \end{aligned}$$

These two equations can be solved simultaneously for r_L and k to obtain

$$\begin{aligned} k &= \frac{1}{2r_E}q^2, \\ r_L &= q + \frac{1}{q} - \frac{q}{2r_E}. \end{aligned}$$

We can then substitute these expressions into the problem of maximizing borrower surplus with the maximization now taken with respect to q so that $\max_q BS = q\left(R - q - \frac{1}{q} + \frac{q}{2r_E}\right) = qR - q^2 - 1 + \frac{q^2}{2r_E}$. The derivative yields

$$\frac{\partial BS}{\partial q} = R - 2q + \frac{q}{r_E}, \tag{20}$$

with the second derivative given by $\frac{\partial^2 BS}{\partial q^2} = -2 + \frac{1}{r_E} < 0$, so that BS is concave in q. Note now that $\left.\frac{\partial BS}{\partial q}\right|_{q=0} = R > 0$, so that clearly $q > 0$ is optimal. Setting (20) equal to zero and solving for q, we obtain $q^* = \frac{R}{2-\frac{1}{r_E}}$. From this we see that for $R > 2 - \frac{1}{2r_E}$, $q^* > 1$, so that the solution must have $q = 1$. Moreover, from above we know that for $q = 1$, $BS = SW > 0$ for $R > 2 - \frac{1}{2r_E}$. This gives part A of the proposition.

Finally, consider the case where $R < 2 - \frac{1}{2r_E}$, so that $q < 1$. Substituting the optimal value of q into BS we obtain:

$$BS = \left(\frac{R}{2-\frac{1}{r_E}}\right)R - \left(\frac{R}{2-\frac{1}{r_E}}\right)^2 - 1 + \frac{\left(\frac{R}{2-\frac{1}{r_E}}\right)^2}{2r_E} = \frac{R^2}{4\left(1-\frac{1}{2r_E}\right)} - 1.$$

Note, however, that $\frac{R^2}{4\left(1-\frac{1}{2r_E}\right)} = \frac{R^2}{2\left(2-\frac{1}{r_E}\right)} = \frac{R^2}{\left(2-\frac{1}{r_E}\right)^2}\frac{\left(2-\frac{1}{r_E}\right)}{2} = q^2\frac{\left(2-\frac{1}{r_E}\right)}{2} < 1$ since $q = \frac{R}{2-\frac{1}{r_E}} < 1$. Therefore, $BS = \frac{R^2}{4\left(1-\frac{1}{2r_E}\right)} - 1 < 0$ for $R < 2 - \frac{1}{2r_E}$. The only feasible optimal solution for the maximization of borrower surplus is then $q = 1$, $k = \frac{1}{2r_E}$, and $r_L = 2 - \frac{1}{2r_E}$ for $R > 2 - \frac{1}{2r_E}$. For $R < 2 - \frac{1}{2r_E}$, no intermediation is possible. This gives part B of the proposition. □

Proof of Proposition 4: As before, the equilibrium value of monitoring q is given by (17) and $r_L \geq 2\sqrt{1-k}$ is needed for an equilibrium to exist when $q < 1$. Assuming that r_L is

large enough, we can calculate

$$\frac{\partial BS}{\partial r_L} = q\left(\frac{(R-r_L)}{\sqrt{r_L^2-4(1-k)}}-1\right). \tag{21}$$

This is positive for $r_L \to 2\sqrt{1-k}$. We then set $\frac{\partial BS}{\partial r_L}=0$ and solve for the loan rate as the necessary first order condition for an interior optimal r_L. The unique solution is

$$\widehat{r}_L \equiv \frac{R}{2}+\frac{2(1-k)}{R}. \tag{22}$$

For $r_L > \widehat{r}_L$, it can be shown that $\frac{\partial BS}{\partial r_L}<0$. To see this substitute $r_L=\widehat{r}_L+\varepsilon$ into (21) to get

$$\frac{\partial BS}{\partial r_L} = \frac{q}{\sqrt{r_L^2-4(1-k)}}\left(R-\widehat{r}_L-\varepsilon-\sqrt{\widehat{r}_L^2-4(1-k)+\varepsilon^2+2\varepsilon\widehat{r}_L}\right).$$

Evaluating the term in brackets at $\varepsilon=0$ gives that it is zero and this in turn means $\frac{\partial BS}{\partial r_L}=0$. We need to show that for $\varepsilon>0$, $\frac{\partial BS}{\partial r_L}$ is negative. Since q and $\sqrt{r_L^2-4(1-k)}$ remain positive what is important is the sign of the term in brackets. Differentiating this with respect to ε gives a negative term and the result follows. It follows from all of this that $BS(r_L)$ is a concave function in the relevant range.

Note also that for

$$r_L > \overline{r}_L \equiv 2-k \geq 2\sqrt{1-k}, \tag{23}$$

it follows from (17) that $q=1$ and for $r_L<\overline{r}_L$, $q<1$.

We now divide the analysis into two cases: (1) $R\geq 2$; and (2) $R<2$.

Case 1: $R\geq 2$. Now $\widehat{r}_L > \overline{r}_L$ for $R>2$. To see this note that $\widehat{r}_L=\overline{r}_L$ at $R=2$ and $\frac{\partial(\widehat{r}_L-\overline{r}_L)}{\partial R}=\frac{1}{2}-\frac{2(1-k)}{R^2}>0$ for $R>2$. Given the concavity of $BS(r_L)$ it follows that $\left.\frac{\partial BS}{\partial r_L}\right|_{\overline{r}_L}>0$ for $R>2$. This implies that borrowers always demand a loan rate equal to $r_L=\overline{r}_L=2-k$ so that $q=1$ as long as this satisfies the bank's participation constraint, $\Pi\geq 0$, which it does for $k\leq\frac{1}{2r_E}$. For $k>\frac{1}{2r_E}$ such that the bank's participation constraint binds, we need to set r_L to satisfy $\Pi(r_L|k)=0$.

Assuming the bank's participation constraint is satisfied, we can now turn to the problem in the first stage to determine k. Since $q=1$ the problem simplifies to

$$\max_k SW = R-\frac{3}{2}+k(1-r_E).$$

The first order condition yields $\frac{\partial SW}{\partial k}=1-r_E<0$, so that $k=0$ is optimal. We check that this solution does in fact satisfy the bank's participation constraint, as $\Pi=qr_L-(1-k)-kr_E-\frac{1}{2}q^2=2-k-(1-k)-kr_E-\frac{1}{2}=\frac{1}{2}>0$. Therefore, $k=0$, $q=1$, and $r_L=2$ is a candidate solution for $R\geq 2$. That it is also the optimal solution can be seen from noting that higher values of k cannot increase q further, so that any solution with $k>\frac{1}{2r_E}$ and r_L determined from $\Pi(r_L|k)=0$ when the bank's participation constraint binds must necessarily lead to lower SW.

Case 2: $R<2$. We know that a minimum condition for an equilibrium to exist is that

$r_L \geq 2\sqrt{1-k}$. Solving for k, this is equivalent to requiring $k \geq 1 - \frac{r_L^2}{4}$. For $r_L = R$, this implies $k^{\min} = 1 - \frac{R^2}{4}$ as an absolute lower bound on the level of capital that is consistent with equilibrium.

Using (22) and (23) it can be seen that

$$\widehat{r}_L - \overline{r}_L = \frac{R}{2} + \frac{2}{R} - 2 - k(\frac{2}{R} - 1).$$

Substituting $k^{\min}$ and rearranging gives

$$\widehat{r}_L - \overline{r}_L = -(1 - \frac{R}{2})^2 < 0.$$

Taking these together it follows that $\widehat{r}_L < \overline{r}_L$ for $R < 2$ and from this also that $q(\widehat{r}_L) < 1$.

Define now r_L^B as the loan rate that satisfies the bank's participation constraint with equality, that is $\Pi(r_L^B|k) = 0$. Also $\frac{\partial \Pi}{\partial r_L} = (r_L - q)\frac{\partial q}{\partial r_L} + q > 0$. If, for a given k, $\widehat{r}_L > r_L^B$, then at the optimum borrowers choose $r_L = \widehat{r}_L$, and $q < 1$, $\Pi > 0$. If, however, for a given k, $\widehat{r}_L < r_L^B$, then $\widehat{r}_L$ is no longer a feasible solution since $\Pi(\widehat{r}_L) < \Pi\left(r_L^B\right) = 0$. In this case, the optimal loan rate is the lowest rate for which $\Pi = 0$, which is r_L^B. This is because no lower rate is feasible since $\Pi(r_L) < 0$ for any $r_L < r_L^B$. A higher r_L is feasible but not optimal since it follows from the concavity of BS that BS must be decreasing for $r_L > \widehat{r}_L$.

The analysis above demonstrates that we have two candidate solutions: either $r_L = r_L^B$ with $\Pi\left(r_L^B\right) = 0$, or $r_L = \widehat{r}_L$ with $\Pi(\widehat{r}_L) \geq 0$. The level of k chosen by the regulator remains to be determined for the two r_L. Start with the case where $r_L = r_L^B$, so that $\Pi\left(r_L^B\right) = 0$. Here, the maximization of SW is equivalent to the maximization of BS, for which we know from Proposition 3 that the solution involves $q = 1$ and $r_L = 2 - k$. This implies $\Pi = \frac{1}{2} - kr_E$, and since by assumption we have $\Pi = 0$, this implies that $k = \frac{1}{2r_E}$ at the optimum. Under this solution social welfare equals

$$SW = qR - (1-k) - kr_E - \frac{1}{2}q^2 = R - \frac{3}{2} + \frac{1}{2r_E}(1 - r_E) = R - 2 + \frac{1}{2r_E}.$$

We note that $SW \geq 0$ for $R \geq 2 - \frac{1}{2r_E}$.

Next, consider the candidate loan rate $r_L = \widehat{r}_L = \frac{R}{2} + \frac{2(1-k)}{R}$, with $q < 1$. For this solution to be feasible, it must satisfy $\Pi \geq 0$, so that the bank's participation constraint does not bind. Substituting the equilibrium loan rate into the bank's monitoring effort as in (17), we have

$$q = \frac{1}{2}\left(\frac{R}{2} + \frac{2(1-k)}{R} \pm \left(\frac{R}{2} - \frac{2(1-k)}{R}\right)\right).$$

Taking the positive root, $q = \frac{R}{2}$, while taking the negative root, $q = \frac{2(1-k)}{R}$. Note first that, for $R < 2$, $\frac{R}{2} > \frac{2(1-k)}{R}$ for $k \geq 1 - \frac{R^2}{4}$, so that the level of monitoring with the positive root Pareto dominates that with the negative root. Furthermore, $\frac{\partial q}{\partial k} = 0$ and $\frac{\partial q}{\partial k} = \frac{-2}{R}$ for the positive and negative roots, respectively. Consider now social welfare, and note that $\frac{\partial SW}{\partial k} = \frac{\partial q}{\partial k}(R - q) + (1 - r_E)$. For $\frac{\partial q}{\partial k} = 0$, $\frac{\partial SW}{\partial k} = 1 - r_E < 0$, while for $\frac{\partial q}{\partial k} = \frac{-2}{R}$, $\frac{\partial SW}{\partial k} = \frac{-2}{R}(R - q) + (1 - r_E) < 0$, so that either way the regulator prefers the lowest possible

k. From above, this lowest value is given by $k = 1 - \frac{R^2}{4}$.

Now $\widehat{r}_L = R$ when evaluated at $k = 1 - \frac{R^2}{4}$. For this level of k and r_L, $BS = 0$. However, $q = \frac{R}{2}$, which implies

$$SW = \Pi = \frac{R^2}{8} - (1 - \frac{R^2}{4})r_E.$$

We compare the two candidate solutions to find which yields the higher social welfare. This amounts to finding the minimum value of R such that

$$\frac{R^2}{8} - (1 - \frac{R^2}{4})r_E \geq R - 2 + \frac{1}{2r_E} > 0.$$

This value is given by

$$R_{AB} = \frac{4r_E + 2\sqrt{r_E + 2r_E^2 - 6r_E^3 + 4r_E^4}}{r_E + 2r_E^2},$$

so that, for $R > R_{AB}$, SW is maximized by setting $k = 1 - \frac{R^2}{4}$, with $q = \frac{R}{2}$, $r_L = R$, and $\Pi = SW > 0$. This is part A.2 in the proposition. For $R < R_{AB}$, SW is maximized by setting $k = \frac{1}{2r_E}$, with $q = 1$, $r_L = 2 - k$, $\Pi = 0$ and $SW = R - 2 + \frac{1}{2r_E}$. This is part B of the proposition.

Finally, if $R - 2 + \frac{1}{2r_E} < 0$ no intermediation occurs and this is part C of the proposition. □

Proof of Proposition 6: Now that there is deposit insurance $r_D = 1$ and (2) simplifies to

$$q = \min\{r_L - (1 - k), 1\}. \tag{24}$$

The bank sets r_L and k to maximize its expected profits. Thus, we have

$$\frac{\partial \Pi}{\partial r_L} = \frac{\partial q}{\partial r_L}(r_L - (1 - k)) + q - q\frac{\partial q}{\partial r_L},$$

which equals 1 if $q = 1$ and equals q if $q < 1$ since from (24), $\frac{\partial q}{\partial r_L} = 1$. In both cases $\frac{\partial \Pi}{\partial r_L} > 0$ so that $r_L = R$. Substituting this into the expression for the expected profits and differentiating it with respect to k, we have

$$\frac{\partial \Pi}{\partial k} = \frac{\partial q}{\partial k}(R - (1 - k)) + q - r_E - q\frac{\partial q}{\partial k},$$

which is equal to $1 - r_E < 0$ if $q = 1$ and is equal to $q - r_E < 0$ if $q < 1$ since $\frac{\partial q}{\partial k} = 1$. The solution must therefore have $k = 0$. Substituting $k = 0$ and $r_L = R$ implies $q = \min\{R - 1, 1\}$. Thus $q = 1$ for $R \geq 2$ and this gives part A of the proposition. For $R \in [1, 2]$ $q = R - 1$ and this gives part B of the proposition. □

Proof of Proposition 7: As before, the bank chooses $r_L = R$ to maximize its expected profit and

$$q = \min\{R - (1 - k), 1\}. \tag{25}$$

Consider first the case where $q = 1$. Then

$$\frac{\partial SW}{\partial k} = 1 - r_E < 0$$

so that $k = 0$. Substituting this in the expression for q, we have again that $q = 1$ if $R \geq 2$. Part A of the proposition follows.

Consider now the case where $q < 1$. Differentiating SW with respect to k, we have

$$\begin{aligned} \frac{\partial SW}{\partial k} &= \frac{\partial q}{\partial k} R + 1 - r_E - q\frac{\partial q}{\partial k} \\ &= 2 - r_E - k = 0 \end{aligned}$$

so that $k = 2 - r_E > 0$ if $r_E < 2$ and $k = 0$ if $r_E \geq 2$.

Substituting for k in the expression for q in (25), if $2 > R \geq r_E$ we have $q = 1$ and then the bank chooses the minimum level of k which guarantees this. This is obtained from setting (25) equal to one, and yields $k^{reg} = 2 - R$ as in part B of the proposition. Alternatively, we have $q = R + 1 - r_E < 1$ for $R < r_E \leq 2$ as in part C, and $q = R - 1 < 1$ for $r_E > 2$, as in part D.

Finally, consider the boundary for $SW \geq 0$ in Figure 4. In Region A $SW > 0$ always as $R > 2$. In Region B solving $SW = 0$ for R we have $R_{BE} = 2 - \frac{1}{2r_E}$ so that $SW \geq 0$ for $R \geq R_{BE}$. Doing the same in Region C we find that $SW \geq 0$ for $R \geq R_{CE} = r_E - 2 + \sqrt{3 + 4r_E - 2r_E^2}$. Both R_{BE} and R_{CE} intersect the line $R = r_E$ at $r_E = 1 + \frac{1}{\sqrt{2}}$. In Region D $SW \geq 0$ for $R \geq R_{DE} = \sqrt{3}$. Below these boundaries $SW < 0$. □

Proof of Proposition 9: We proceed in four steps. We first show that $k < 1$, $r_L < R$ and $\Pi = 0$; we then characterize the two parts A and B of the proposition (see Figure 5).

Step 1: We start by showing that $k = 1$ is not possible. Suppose $k = 1$. If $q = 1$, it must then be, from (24), that $r_L \geq 2 - k = 1$. $BS = R - r_L$ is maximized at the lowest value of r_L consistent with $\Pi \geq 0$. For $k = q = 1$, $\Pi = r_L - r_E - \frac{1}{2}$ which is nonnegative if and only if $r_L \geq r_E + \frac{1}{2}$. Now, for any $r_L \geq r_E + \frac{1}{2}$ and $k = q = 1$, $BS \leq R - r_E - \frac{1}{2}$. Since $q = 1$, we can keep Π constant by lowering both k and r_L simultaneously. Specifically, reduce k by some small amount Δk, and reduce r_L by an amount $\Delta r_L = -\Delta k(1 - r_E)$. This maintains Π constant and $q = 1$, but strictly increases BS. Therefore, $k = 1$, $q = 1$ cannot be optimal.

Suppose now $k = 1$ but $q = r_L - (1 - k) = r_L < 1$. Substituting again in the expression for Π, we have

$$\Pi = \frac{1}{2} r_L^2 - r_E < 0$$

for $r_L < 1$ and $r_E \geq 1$. This implies that also $k = 1$, $q < 1$ cannot be optimal. Therefore, any solution must have $k < 1$.

Step 2: We now show that $r_L < R$ must hold. Suppose $r_L = R$ so that $BS = 0$. This cannot be optimal since it is always possible to do better than this by choosing r_L and k such that $1 < r_L < R$ so $q = \min\{r_L - (1 - k), 1\} > 0$, $\Pi \geq 0$, and $BS = q(R - r_L) > 0$.

Step 3: We next show that $\Pi = 0$ in equilibrium. Suppose to the contrary that $\Pi > 0$. Then, if $q < 1$ and $k < 1$ we have $BS = (r_L - (1 - k))(R - r_L)$ and $\partial BS/\partial k = R - r_L > 0$

for all k. However, this gives a contradiction as it is inconsistent with $k < 1$. Next consider $q = 1$ and $k < 1$. The former implies $r_L \geq 2 - k$ and maximizing $BS = (R - r_L)$ leads to $r_L = 2 - k$. Now it is possible to increase BS by lowering r_L further and increasing k until $k = \frac{1}{2r_E}$. This satisfies $\Pi = r_L - (1-k) - kr_E - \frac{1}{2} = 0$ and contradicts the initial assumption of $\Pi > 0$.

Step 4: We now turn to the expressions for k, r_L and q knowing that $k < 1$, $r_L < R$ and $\Pi = 0$. There are two possibilities for the monitoring effort, $q = 1$ and $q < 1$, and these correspond to parts A and B in the proposition.

Consider $q < 1$ first. This implies $q = r_L - (1 - k) < 1$. From the constraint $\Pi = 0$ we obtain

$$\Pi = \frac{1}{2}(r_L - (1-k))^2 - kr_E = 0.$$

After rearranging and taking square roots, we have

$$r_L = 1 - k + \sqrt{2r_E k} \qquad \text{and} \qquad q = \sqrt{2r_E k} < 1. \tag{26}$$

The last inequality implies $k < \overline{k} = \frac{1}{2r_E}$ for $q < 1$. Given (26), it follows that

$$BS(k) = \sqrt{2r_E k}[R - 1 + k - \sqrt{2r_E k}], \tag{27}$$

from which

$$\frac{\partial BS}{\partial k} = \sqrt{\frac{r_E}{2k}}(R-1) + \frac{3}{2}\sqrt{2r_E k} - 2r_E. \tag{28}$$

Putting $\frac{\partial BS}{\partial k} = 0$, multiplying through by $k^{1/2}$, solving for $k^{1/2}$ and squaring, we obtain

$$k = \left(\frac{\sqrt{2r_E} \pm \sqrt{2r_E - 3(R-1)}}{3} \right)^2.$$

This gives two distinct roots for $2r_E - 3(R-1) > 0$ or, equivalently, $R < \frac{2r_E}{3} + 1$. Since $BS|_{k=0} = 0$ and $\frac{\partial BS}{\partial k}\big|_{k=0} > 0$, the root for k with a minus, k^{INT}, is a local maximum while the root with a plus, k^{MIN}, is a local minimum. To see then whether k^{INT} is a global maximum, we first note that $\overline{k}$ is the maximum possible optimal value of k since for $k > \frac{1}{2r_E}$, $q = 1$, $BS = R - r_L$ with $r_L = 3/2 + k(r_E - 1)$ satisfying the constraint $\Pi = 0$, and

$$\frac{\partial BS}{\partial k} = -(r_E - 1) < 0, \tag{29}$$

so that $k > \overline{k}$ is never optimal for borrowers. Then, we compare k^{INT} and k^{MIN} with $\overline{k} = \frac{1}{2r_E}$. To do this, we distinguish between two cases given by $r_E > \frac{3}{2}$ and $r_E \leq \frac{3}{2}$.

(i) Consider $r_E > \frac{3}{2}$. Setting $k^{INT} = \overline{k}$ and solving for R yields

$$R = R_{AB} = 3 - \frac{3}{2r_E}.$$

Since k^{INT} is increasing in R, this implies that $k^{INT} < \overline{k}$ for $R < 3 - \frac{3}{2r_E}$. Now notice that

for $r_E > \frac{3}{2}$ it is the case that

$$\overline{k}^{1/2} = \frac{1}{\sqrt{2r_E}} < \frac{1}{\sqrt{3}} < \frac{1}{\sqrt{3}}\frac{\sqrt{2r_E}}{\sqrt{3}} = \frac{\sqrt{2r_E}}{3}.$$

This inequality together with $\left(\frac{\sqrt{2r_E}}{3}\right)^2 < k^{MIN}$ implies $\overline{k} < k^{MIN}$. Thus, if $r_E > \frac{3}{2}$, we have $k^{INT} < \overline{k} < k^{MIN}$ for $R < R_{AB}$. This, together with (29) and the fact that from (28) $\frac{\partial BS}{\partial k}\big|_{k=\overline{k}} = r_E\left(R - 3 + \frac{3}{2r_E}\right) < 0$, implies that $BS(k^{INT}) > BS(\overline{k})$ and therefore that k^{INT} is the global maximum for $R < R_{AB}$ and $r_E > \frac{3}{2}$. By contrast, for $R_{AB} < R < \frac{2r_E}{3} + 1$, $k^{INT} > \overline{k}$ and $\overline{k} = \frac{1}{2r_E}$ is the global optimum since $q = 1$, $\frac{\partial BS}{\partial k}\big|_{k=\overline{k}} > 0$ and as in (29) $\partial BS/\partial k < 0$ for $k > \frac{1}{2r_E}$. Finally, for $R > \frac{2r_E}{3} + 1$, no real value for k^{INT} exists. It follows that for $0 \leq k < \frac{1}{2r_E}$, $\partial BS/\partial k > 0$. Similarly to (29), $\partial BS/\partial k < 0$ for $k > \frac{1}{2r_E}$. Thus $k = \frac{1}{2r_E}$ is the global maximum and $q = 1$.

(ii) Consider now $r_E < \frac{3}{2}$. Here it is the case that

$$\overline{k}^{1/2} = \frac{1}{\sqrt{2r_E}} > \frac{1}{\sqrt{3}} > \frac{1}{\sqrt{3}}\frac{\sqrt{2r_E}}{\sqrt{3}} = \frac{\sqrt{2r_E}}{3},$$

so that $k^{INT} < \overline{k}$. Now $k^{MIN} = \overline{k}$ for $R = 3 - \frac{3}{2r_E}$, and $k^{MIN} > \overline{k}$ for $R < 3 - \frac{3}{2r_E}$ since k^{MIN} is decreasing in R. This implies that k^{INT} is the global optimum for $R \leq 3 - \frac{3}{2r_E}$ using a similar argument to the one above for $r_E > \frac{3}{2}$. On the other hand, for $R > 3 - \frac{3}{2r_E}$, $k^{MIN} < \overline{k}$ and therefore $BS(k^{INT})$ could be higher or lower than $BS(\overline{k})$. To see when $BS(k^{INT}) > BS(\overline{k})$, set them equal to each other and solve for R. Denoting this value by R_{AB}, it can be shown $R_{AB} = \frac{3}{2} - \frac{3}{8r_E} + \frac{r_E}{2}$. Then the global optimum is at $k = k^{INT}$ for $R < R_{AB}$ and at $k = \overline{k} = \frac{1}{2r_E}$ for $R \geq R_{AB}$.

Together (i) and (ii) give the boundary for parts A and B of the proposition and the values of k^{BS}, r_L, and q. In part A $BS = SW = q(R - r_L) = R - (2 - \frac{1}{2r_E})$ and in part B $BS = q(R - 1 + k^{BS} - q)$ and $SW = BS - (1 - q)(1 - k^{BS}) = qR - q^2 - (1 - k^{BS})$.

Finally, consider the boundary where $SW = 0$ illustrated in Figure 5. In Region A $SW = R - (2 - \frac{1}{2r_E})$. Evaluating this at the boundary for Region A for $r_E < \frac{3}{2}$, $R_{AB} = \frac{3}{2} - \frac{3}{8r_E} + \frac{r_E}{2}$ gives $SW|_{R_{AB}} = \frac{(1-2r_E)^2}{8r_E} > 0$. This implies that social welfare is positive at the boundary as well as above it. The same holds for $r_E \geq \frac{3}{2}$, since evaluating social welfare at $R_{AB} = 3 - \frac{3}{2r_E}$, we obtain $SW|_{R_{AB}} = 1 - \frac{1}{r_E} > 0$.

Consider now social welfare in Region B as given by $SW = qR - q^2 - (1 - k^{BS})$. Evaluating this at $R_{AB} = \frac{3}{2} - \frac{3}{8r_E} + \frac{r_E}{2}$ for $r_E < \frac{3}{2}$ gives $SW|_{R_{AB}} = \frac{5 - 46r_E + 44r_E^2 - 8r_E^3}{16r_E}$. This equals zero at $r_E = 1.226$, is negative for $r_E < 1.226$ and positive for $1.226 \leq r_E < 1.5$. Consider now the case $r_E \geq \frac{3}{2}$. It can be checked that for $r_E \geq 1.226$ there exists a boundary $\widehat{R}$ as defined implicitly by $SW = qR - q^2 - (1 - k^{BS}) = 0$ such that $SW \geq 0$ for $R \geq \widehat{R}$ and $SW < 0$ otherwise. □

Proof of Proposition 10: We proceed in two steps. We first describe how the optimal amount of capital k is determined depending on which constraints bind. Then we find the

global optimum k^{REG} as a function of the parameters R and r_E.

Step 1. We start by determining the optimal amount of capital k depending on the constraints $\Pi \geq 0$ and $q \leq 1$ in the maximization problem.

Case 1: Unconstrained case ($\Pi > 0$) for $q < 1$. If $q = r_L - (1-k) < 1$, then from the first order condition $\partial BS/\partial r_L = 0$ we have

$$r_L = \frac{R + (1-k)}{2}, \tag{30}$$

so that

$$q = \frac{R - (1-k)}{2} < 1. \tag{31}$$

Substituting these expressions for q and r_L into (14) gives:

$$SW_U(k) = R\left(\frac{R-(1-k)}{2}\right) - (1-k) - kr_E - \frac{1}{2}\left(\frac{R-(1-k)}{2}\right)^2, \tag{32}$$

from which

$$\frac{\partial SW_U}{\partial k} = \frac{R}{4} + \frac{1-k}{4} + 1 - r_E, \tag{33}$$

and

$$\frac{\partial^2 SW_U}{\partial k^2} = -\frac{1}{4} < 0$$

so SW_U is a concave function. Given this, there are three possibilities for the optimal value of k when $\Pi > 0$:

(i) $\frac{\partial SW_U}{\partial k} < 0$, in which case $k = 0$ is optimal.

(ii) $\frac{\partial SW_U}{\partial k} = 0$, in which case there is an interior optimum given by

$$k_U^{INT} = R + 1 - 4(r_E - 1) \tag{34}$$

and

$$SW_U(k_U^{INT}) = 2 + 2r_E^2 - r_E(5+R) + R + \frac{R^2}{2}. \tag{35}$$

(iii) $\frac{\partial SW_U}{\partial k} > 0$, in which case the optimum equates the value of k at which either the constraint $\Pi \geq 0$ or the constraint $q \leq 1$ start to be binding. To find where $\Pi = 0$ binds, we substitute the expressions for q and r_L as given by (31) and (30) into (13) and obtain

$$\Pi_U = \frac{1}{2}\left(\frac{R-(1-k)}{2}\right)^2 - kr_E. \tag{36}$$

Setting $\Pi_U = 0$ and solving for k gives the value k_0 where the constraint starts to bind

$$k_0 = 1 + 4r_E - R - 4\sqrt{r_E}\sqrt{\frac{1}{2} + r_E - \frac{1}{2}R}. \tag{37}$$

The constraint $q \leq 1$ starts instead to bind at $k = \overline{k}_U$, where $\overline{k}_U$ equates (31) to 1 and is

equal to

$$\bar{k}_U = 3 - R. \tag{38}$$

Thus, the optimal value of k when $\frac{\partial SW_U}{\partial k} > 0$ is at $k = k_0$ if $k_0 < \bar{k}_U$ and at $k = \bar{k}_U$ if instead $k_0 > \bar{k}_U$.

Case 2: Constrained case ($\Pi = 0$) for $q < 1$. When $\Pi = 0$, as in (26) we have $r_L = 1 - k + \sqrt{2r_E k}$, and $q = \sqrt{2r_E k}$. Substituting these into (14) gives

$$SW_C = \sqrt{2r_E k}R - (1 - k) - 2r_E k, \tag{39}$$

from which

$$\frac{\partial SW_C}{\partial k} = \sqrt{\frac{r_E}{2}}k^{-1/2}R + 1 - 2r_E,$$

and

$$\frac{\partial^2 SW_C}{\partial k^2} = -\frac{1}{2}\sqrt{\frac{r_E}{2}}k^{-3/2}R < 0.$$

Thus again SW_C is a concave function of k with also $\frac{\partial SW_C}{\partial k}\big|_{k=0} > 0$. This implies that there are two possibilities for the optimal value of k when $\Pi = 0$ and $q < 1$:

(i) $\partial SW_C/\partial k = 0$, so that there is an interior optimum given by

$$k_C^{INT} = \frac{r_E R^2}{2(2r_E - 1)^2}. \tag{40}$$

(ii) $\partial SW_C/\partial k > 0$, so that the optimum k is where the constraint $q \leq 1$ starts to be binding. From $q = 1$, this happens when

$$\bar{k}_C = \frac{1}{2r_E} < 1 \text{ since } r_E \geq 1, \tag{41}$$

and the optimal value of k is at $k = \bar{k}_C$ if $\bar{k}_C < k_C^{INT}$. Substituting $\bar{k}_C$ in (39) gives

$$SW_C(\bar{k}_C) = R - 2 + \frac{1}{2r_E}. \tag{42}$$

Case 3: Unconstrained case ($\Pi > 0$) for $q = 1$. From $q = 1$, it follows $r_L = 2 - k$. Substituting $q = 1$ into (14), we then have

$$SW_{U1} = R - (1 - k) - kr_E - \frac{1}{2}$$

from which

$$\frac{\partial SW_{U1}}{\partial k} = 1 - r_E < 0 \tag{43}$$

as $r_E > 1$. Thus, the only possible optimal value for k when $\Pi > 0$ and $q = 1$ is at the value where the constraint $q = 1$ starts to be binding, obtained from the first order condition in (30), which gives $k = \bar{k}_U = 3 - R$.

Case 4: Constrained case ($\Pi = 0$) for $q = 1$. Substituting $q = 1$ in (14) we obtain $SW_{C1} = SW_{U1} = R - (1 - k) - kr_E - \frac{1}{2}$ and thus $\frac{\partial SW_{C1}}{\partial k} = 1 - r_E < 0$. Then the only possible optimum in this case is the lowest value of k such that $\Pi = 0$ and $q = 1$ as given by $\overline{k}_C = \frac{1}{2r_E}$.

At $k = 0$ it follows from (31) that $q < 1$ if $R < 3$ and from (36) that

$$\Pi_U|_{k=0} = \frac{1}{2}\left(\frac{R-1}{2}\right)^2 > 0.$$

This implies that there is always an unconstrained region with $q < 1$ for sufficiently small values of k when $R < 3$. At k_0 the profit constraint begins to bind. At this point both the unconstrained and the constrained solutions are the same. For higher values of k there is a constrained region. In determining the global optimum the potential values of k are $0, \overline{k}_U, k_0, k_U^{INT}, \bar{k}_C$ or k_C^{INT}. In fact it is possible to show that in all the regions where $SW \geq 0, \bar{k}_C < k_C^{INT}$. This will be done after considering all the regions and the other constraints.

Step 2. Now that we have derived the possible cases depending on the constraints $\Pi \geq 0$ and $q \leq 1$ and the optimal values of k in each of them, we analyze how the two constraints move as a function of the parameters r_E and R, and determine the global optimal value for k in each scenario. The regions refer to those in Figure 6.

*Region A***:** When $R \geq 3$ the optimal solution for k is $k = 0$ in the unconstrained case with $q = 1$. For $R \geq 3$, the constraint $q = 1$ binds already at $k = 0$ from (31), and given (43), that is also the global optimum. From the expressions in Step 1 for the unconstrained region it can be seen that with $k = 0$, and $q = 1, r_L = \frac{R+1}{2}, BS = \frac{1}{2}(R-1) > 0, \Pi = \frac{R}{2} - 1 > 0$ and $SW = R - \frac{3}{2} > 0$.

Region B: In this region the global optimum is at $k = \bar{k}_U = 3 - R$ in the unconstrained case ($\Pi > 0$) with $q = 1$. This requires:

$$\bar{k}_U \leq k_0, \quad \partial SW_U/\partial k|_{k=0} > 0, \quad k_U^{INT} \geq \bar{k}_U, \quad \bar{k}_U \geq 0.$$

The first condition assures that the constraint $q = 1$ hits before the $\Pi = 0$ constraint and we can only consider the unconstrained region. Using (38) and (37) it can be seen that the condition is satisfied for $R \geq R_{BE}$, where R_{BE} is the boundary between regions B and E, defined by

$$R_{BE} = 3 - \frac{1}{2r_E}. \tag{44}$$

The next two conditions ensure that $\bar{k}_U$ is optimal in the unconstrained region and thus also globally optimal; it can be seen from (33), (34) and (38) that they are both satisfied for $R \geq R_{BC}$, where R_{BC} gives the boundary between regions B and C and is defined by

$$R_{BC} = 2r_E - 1. \tag{45}$$

The last condition just requires $\bar{k}_U$ to be non-negative and is satisfied for $R \leq 3$. This implies that the boundary with region A is at $R = 3$ as shown above.

Finally, using $k = \bar{k}_U = 3 - R$ and $q = 1$ in the expressions for the unconstrained case we obtain $r_L = R - 1$, $BS = 1$, $\Pi = \frac{1}{2} - (3 - R)r_E > 0$, and $SW = \frac{1}{2} - (3 - R)r_E > 0$.

Region C: In this region the global optimum value is at k_U^{INT} in the unconstrained case for $q < 1$. For this it is needed that

$$k_U^{INT} \leq \bar{k}_U, \quad k_U^{INT} \leq k_0, \quad \partial SW_U/\partial k|_{k=0} \geq 0, \quad \bar{k}_C < k_C^{INT}, \quad SW_U(k_U^{INT}) \geq SW_C(\bar{k}_C).$$

The first three inequalities guarantee that k_U^{INT} is optimal in the unconstrained case, while the last two ensure that k_U^{INT} is also the global optimum.

The first inequality is satisfied for $R \leq R_{BC}$, where R_{BC} is given by (45). The second inequality will be shown to be satisfied below. The third inequality implies from (33) that

$$\left.\frac{\partial SW_U}{\partial k}\right|_{k=0} = \frac{R}{4} + \frac{1}{4} + 1 - r_E \geq 0, \tag{46}$$

or equivalently

$$R \geq R_{CD} = 4r_E - 5. \tag{47}$$

where R_{CD} defines the boundary between regions C and D.

The fourth inequality is shown to be satisfied at the end of the proof of this proposition. The fifth inequality is satisfied for $R \geq R_{CE}$, with R_{CE} found by equating the expressions for $SW_U(k_U^{INT})$ and $SW_C(\bar{k}_C)$ as found in (35) and (42) to give

$$R_{CE} = r_E + \frac{\sqrt{r_E - 8r_E^2 + 10r_E^3 - 3r_E^4}}{r_E}. \tag{48}$$

It can be seen that the intersection of boundaries R_{BC} and R_{CD} is at $r_E = 2$ and $R = 3$. It can also be checked that R_{BE}, R_{BC} and R_{CE} intersect at $r_E = 1.866$ and $R = 2.732$. Also R_{CD} and R_{CE} intersect at $r_E = 1.933$ and $R = 2.732$.

With regard to the constraint $k_U^{INT} \leq k_0$, it can be seen using (34) and (37) that this is equivalent to $R \leq 3r_E - 2 - \sqrt{3}\sqrt{2r_E - r_E^2}$. It can be checked that Region C lies below this constraint.

To conclude, the optimal value of k is $k_U^{INT} = R+1-4(r_E-1)$, and using the expressions for the unconstrained region $r_L = 2(r_E-1)$, $q = R-2(r_E-1) < 1$, $BS = (2-2r_E+R)^2 > 0$, $\Pi = \frac{1}{2}(R+2)^2 - 3(R+3)r_E + 6r_E^2 > 0$ and $SW = \frac{R^2}{2} + R - (R+5)r_E + 2r_E^2 + 2 > 0$.

Region D: In this region the global optimum is at the value $k = 0$ in the unconstrained case ($\Pi > 0$) with $q < 1$. Sufficient conditions for this to hold are:

$$\left.\frac{\partial SW_U}{\partial k}\right|_{k=0} < 0, \quad \bar{k}_C < k_C^{INT}, \quad SW_U(0) \geq SW_C(\bar{k}_C).$$

The first condition assures that $k = 0$ is the optimal value in the unconstrained region, while the second and third assure that $k = 0$ is the global optimum. The first condition is satisfied when $R < R_{CD}$ where R_{CD} is given in (47).

The second inequality is demonstrated at the end of the proof of the proposition. For the third inequality, equating $SW_U(0)$ from (32) with $SW_C(\bar{k}_C)$ from (42) and solving for

the solution that is relevant so that $R > 1$ gives

$$R_{DE} = \frac{5\sqrt{r_E} + 2\sqrt{3 + r_E}}{3\sqrt{r_E}}. \tag{49}$$

The third inequality is therefore satisfied for $R \geq R_{DE}$ and R_{DE} gives the boundary between Regions D and E. Taking the limit as $r_E \to \infty$ it can be seen that $R_{DE} \to 7/3 > 2$. Also it can be checked that R_{DE} intersects with R_{CD} and R_{DE} at $r_E = 1.933$ and $R = 2.732$.

For region D to exist, it must also be that the $q = 1$ constraint does not bind when $\Pi > 0$ at $k = 0$. This guarantees that the unconstrained case with $q < 1$ is the relevant one at $k = 0$. Substituting the expression for r_L as given by (30) in the expression for $q = r_L - (1 - k)$ at the value $k = 0$ yields $q = \frac{R-1}{2}$. Thus, the $q = 1$ boundary starts to bind at $k = 0$ for $R = 3$. This gives the boundary between regions A and D as shown in Figure 6.

With $k = 0$ and $q = \frac{R-1}{2} < 1$, it can be shown in the usual way that $r_L = \frac{R}{2}, BS = \frac{1}{4}R(R-1) > 0, \Pi = \frac{1}{8}(R^2 - 4R + 3) > 0$ and $SW = \frac{1}{8}(3R^2 - 2R - 9) > 0$.

Region E: In Region E the global optimum is at the value $k = \bar{k}_C = \frac{1}{2r_E}$ in the constrained case ($\Pi = 0$) and $q = 1$. Sufficient conditions for this to hold are

$$k_0 \leq \bar{k}_U,\ \bar{k}_C \leq k_C^{INT},\ SW_C(\bar{k}_C) \geq SW_U(k_U^{INT}),\ SW_C(\bar{k}_C) \geq SW_U(0),\ SW_C(\bar{k}_C) \geq SW_U(k_0).$$

The first inequality assures that in addition to $k = 0$ the two relevant cases to consider in the unconstrained region are $\Pi > 0$ with $q < 1$, which is k_U^{INT}, and $\Pi = 0$ with $q < 1$, which is k_0. The second condition guarantees that $\bar{k}_C$ is optimal in the constrained case. The remaining three inequalities ensure that $\bar{k}_C$ is the global optimum by requiring that social welfare in $\bar{k}_C$ be at least as good as in any potential optima in the unconstrained case.

The upper boundary of Region E has been considered in the discussion of Regions B, C and D above. R_{BE} follows from the first inequality, R_{CE} from the third, and R_{DE} from the fourth.

The final inequality follows from the fact that at $k_0, q < 1$ from the first inequality. Given that the unconstrained and constrained solutions coincide at this point and $q = \sqrt{2r_E k}$ is increasing in k at this point it must be the case that $k_0 < \bar{k}_C$. Combining this with the concavity of SW_C and $\bar{k}_C \leq k_C^{INT}$, the inequality follows. As before, we leave $\bar{k}_C \leq k_C^{INT}$ until the end.

Consider next the $BS \geq 0$ participation constraint of the borrowers. Given that in region E $k^{reg} = \frac{1}{2r_E}$, we have $r_L = 1 - k + \sqrt{2r_E k} = 2 - \frac{1}{2r_E}$. Thus the participation constraint becomes $BS = R - 2 - \frac{1}{2r_E} \geq 0$ and the boundary between Regions E and F is

$$R_{EF} = 2 - \frac{1}{2r_E}.$$

Finally, given $k = \frac{1}{2r_E}, q = 1$, and $r_L = 2 - \frac{1}{2r_E}$, it can be shown in the usual way that $BS = SW = R - (2 - \frac{1}{2r_E}) > 0$, and $\Pi = 0$.

Region F: It can be seen that for the optimal solution in Region E where $k = \bar{k}_C = \frac{1}{2r_E}$ in the constrained region, $SW = R - (2 - \frac{1}{2r_E}) < 0$ for $R < R_{EF}$. However, this is not the

only optimal solution in Region F. So far it has been assumed throughout that $\bar{k}_C \leq k_C^{INT}$. If this inequality is reversed then k_C^{INT} is optimal. Using (41) and (40) it can be shown that the boundary for this constraint is

$$R = 2 - \frac{1}{r_E}.$$

For $R > 2 - \frac{1}{r_E}$ we have $\bar{k}_C \leq k_C^{INT}$. Since $2 - \frac{1}{r_E} < 2 - \frac{1}{2r_E}$ it follows that $\bar{k}_C \leq k_C^{INT}$ holds in Regions C, D, and E as required above.

For $R \leq 2 - \frac{1}{r_E}$, k_C^{INT} is the optimal solution. However, it can be shown using the expressions for the constrained solution in step 1 that $SW < 0$ for all these values of R and r_E. Thus $SW < 0$ in the whole of Region F and there is no intermediation. □

Proof of Proposition 11: To prove this, we overlap Figures 5 and 6 and we compare k^{BS} and k^{reg} in each region to give Figure 7. We note first that the boundary between Regions A and B in Figure 5 lies above the one between Regions E and F in Figure 6 and intersects the boundary between regions D and E in Figure 6 at $r_E = 3.52$. We consider now each region of Figure 7 in turn. For clarity, in what follows we define the regions of Proposition 9 as 9.A and 9.B, and those of Proposition 10 as 10.A, 10.B, 10.C, 10.D, 10.E and 10.F. Regions without a prefix refer to Figure 7.

Region A: $k^{BS} > k^{reg}$. This region consists of Regions 10.A, 10.B, 10.C and 10.D. We consider each of them in turn.

Region 10.A.

It can be seen directly that $k^{BS} = \frac{1}{2r_E} > k^{reg} = 0$.

Region 10.B.

In this region for $k^{BS} > k^{reg}$ to hold, it is necessary that $k^{BS} = \frac{1}{2r_E} > k^{reg} = 3 - R$, or equivalently $R > 3 - \frac{1}{2r_E}$.It can be seen directly that Region B satisfies this constraint since the lower boundary is $R_{BE} = 3 - 1/2r_E$.

Region 10.C.

In this region for $k^{BS} > k^{reg}$ to hold, it is necessary that $k^{BS} = \frac{1}{2r_E} > k^{reg} = R + 1 - 4(r_E - 1)$,or equivalently $R \leq 4r_E - 5 + \frac{1}{2r_E}$.It can be seen that the boundary of this intersects with $R = 2r_E - 1$ at the corner of Region 10.C where $R_{BC} = 2r_E - 1$ intersects with $R_{BE} = 3 - 1/2r_E$. It can straightforwardly be checked that apart from this point Region 10.C lies below $R = 4r_E - 5 + \frac{1}{2r_E}$ so that $k^{BS} > k^{reg}$.

Region 10.D.

As already described, the boundary between Regions 9.A and 9.B intersects with the boundary of Region 10.D so that we have to compare k^{BS} as defined both in Regions 9.A and 9.B with k^{reg} in Region 10.D. It is easy to see that $k^{BS} > k^{reg}$ always since $k^{reg} = 0$ in Region 10.D and $k^{BS} > 0$ in both Regions 9.A and 9.B.

Region B: $k^{BS} = k^{reg}$. This region consists of the overlap between Region 9.A and Region 10.E. It can be seen directly from Propositions 9 and 10 that $k^{BS} = k^{reg} = \frac{1}{2r_E}$.

Region C: $k^{BS} < k^{reg}$. This region derives from overlapping Regions 9.B and 10.E. It holds from Propositions 9 and 10 that $k^{BS} = \left(\frac{\sqrt{2r_E} - \sqrt{2r_E - 3(R-1)}}{3}\right)^2$, and $k^{reg} = \frac{1}{2r_E}$. The

boundary $k^{BS} = k^{reg}$ is equivalent to $R = 3 - \frac{3}{2r_E}$. This is the boundary for Regions 9.A and 9.B for $r_E \geq \frac{3}{2}$. Now given that

$$\frac{\partial k^{BS}}{\partial R} = \left(\frac{\sqrt{2r_E} - \sqrt{2r_E - 3(R-1)}}{3} \right) (2r_E - 3(R-1))^{-\frac{1}{2}} R > 0,$$

and that $k^{reg} = 1/2r_E$ is independent of R, it follows that as R falls so does k^{BS}/k^{REG}. Thus, $k^{BS} < k^{reg}$ for $R < 3 - \frac{3}{2r_E}$ and $r_E \geq \frac{3}{2}$.

Consider now $r_E < \frac{3}{2}$. We know from the proof of Proposition 9 that in this case $k^{MIN} = \overline{k}_C$ at $R = 3 - 3/2r_E$ and that at the boundary between Regions 9.A and 9.B,

$$k^{BS} = \left(\frac{\sqrt{2r_E} - \sqrt{2r_E - 3(R-1)}}{3} \right)^2 < \frac{1}{2r_E}.$$

This, together with the fact that $\frac{\partial k^{BS}}{\partial R} > 0$, implies that $k^{BS} < k^{reg}$ is satisfied on the boundary between Regions 9.A and 9.B as well as below it. Thus, $k^{BS} < k^{reg}$.

Region D: $k^{BS} > 0$ and there is no intermediation in the regulatory case. Here the relevant areas are Regions 9.B and 10.F.

The proposition follows. □

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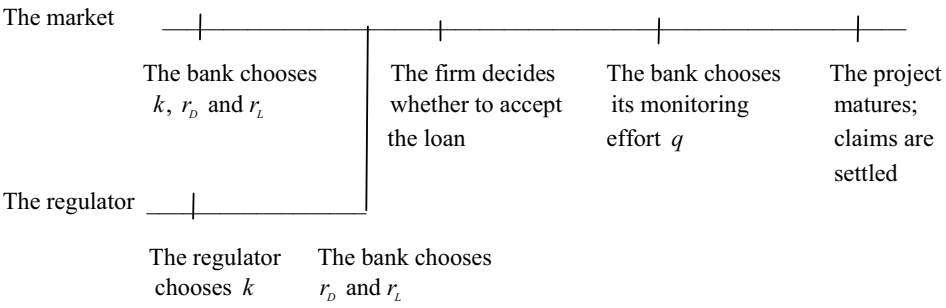

Figure 1: Timing of the model

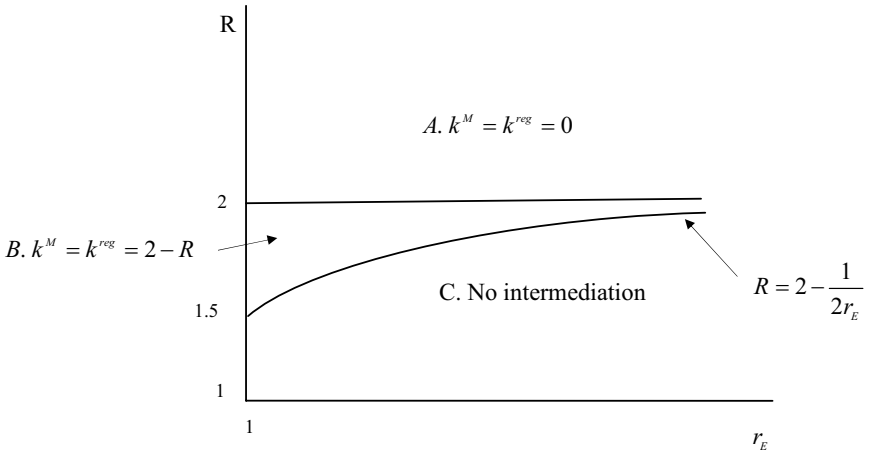

Figure 2: Comparison of market and regulatory solutions with monopoly and no deposit insurance. The figure compares the level of capital in the market solution (k^M) and in the regulatory solution (k^{reg}) in the case of monopoly and no deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes three regions: Region A, as defined by $R \geq 2$, where $k^M = k^{reg} = 0$; Region B, as defined by $2 - 1/2r_E \leq R < 2$, where $k^M = k^{reg} = 2 - R$; and Region C, as defined by $R < 2 - 1/2r_E$, where there is no intermediation.

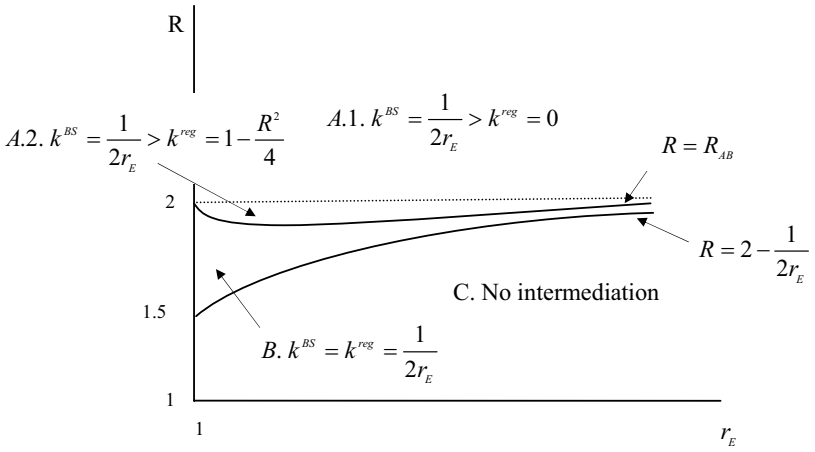

Figure 3: Comparison of market and regulatory solutions with competition and no deposit insurance. The figure compares the level of capital in the market solution (k^{BS}) and in the regulatory solution (k^{reg}) in the case of competition and no deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes four regions: Region A.1, as defined by $R \geq 2$, where $k^{BS} = 1/2r_E > k^{reg} = 0$; Region A.2, as defined by $R_{AB} \leq R < 2$ with $R_{AB} = (4r_E + 2\sqrt{r_E + 2r_E^2 - 6r_E^3 + 4r_E^4})/(r_E + 2r_E^2)$, where $k^{BS} = 1/2r_E > k^{reg} = 1 - R^2/4$; Region B, as defined by $2 - 1/2r_E \leq R < R_{AB}$, where $k^{BS} = k^{reg} = 1/2r_E$; and Region C, as defined by $R < 2 - 1/2r_E$, where there is no intermediation.

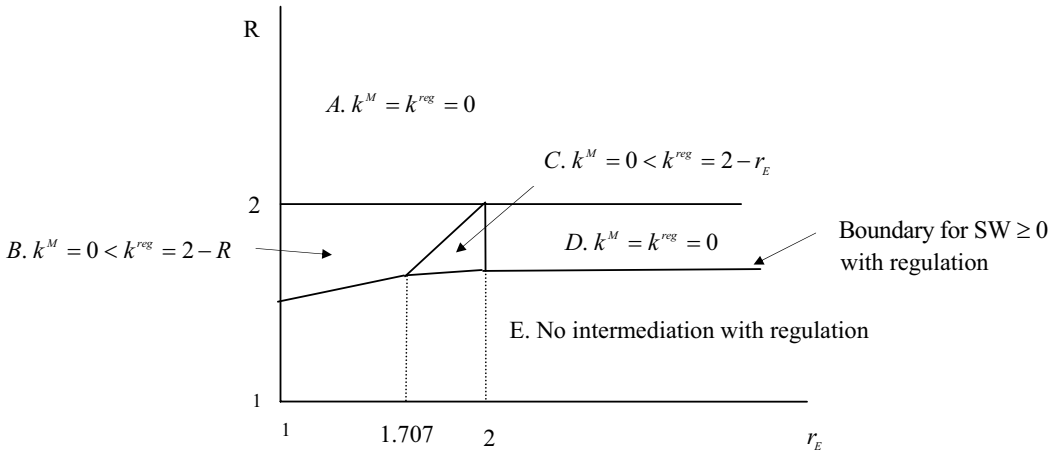

Figure 4: Comparison of market and regulatory solutions with monopoly and deposit insurance. The figure compares the level of capital in the market solution (k^M) and in the regulatory solution (k^{reg}) in the case of monopoly and deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes five regions: Region A, as defined by $R \geq 2$, where $k^M = k^{reg} = 0$; Region B, as defined by $r_E < R_{BE} = 2 - 1/2 r_E < R < 2$, where $k^M = 0 < k^{reg} = 2 - R$; Region C, as defined by $R_{CE} = r_E - 2 + \sqrt{3 + 4r_E - 2r^2{}_E} < R \leq r_E < 2$, where $k^M = 0 < k^{reg} = 2 - r_E$; and Region D, as defined by $R_{DE} = \sqrt{3} < R < 2$ and $r_E \geq 2$, where $k^M = k^{reg} = 0$. The boundaries R_{BE} and R_{CE} intersect the line $R = r_E$ at $r_E = 1.707$

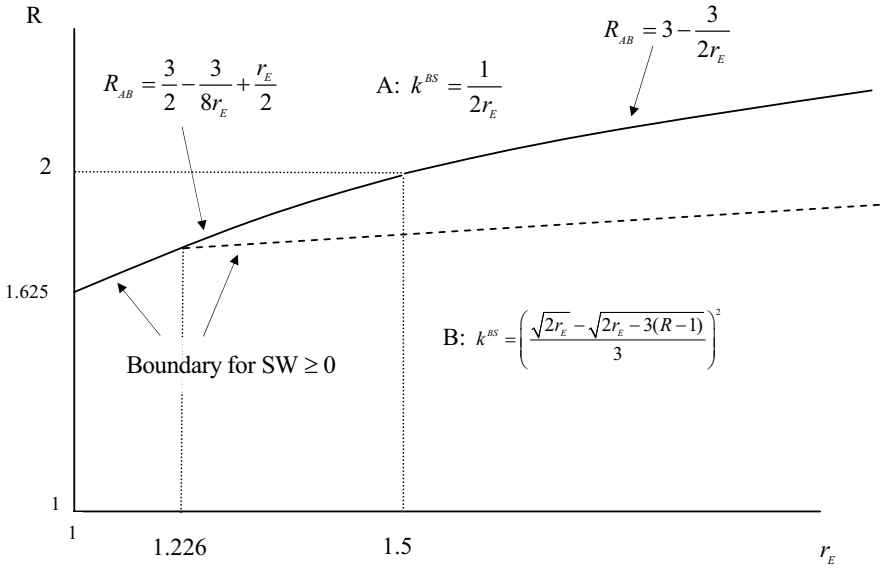

Figure 5: Market solution with competition and deposit insurance. The figure shows the level of capital in the market solution (k^{BS}) for the case of competition and deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes two regions: Region A, as defined by $R \geq R_{AB}$, where $k^{BS} = 1/2r_E$; and Region B, as defined by $R < R_{AB}$, where $k^{BS} = \left(\sqrt{2r_E} - \sqrt{2r_E - 3(R-1)}/3\right)^2$. The boundary between the two regions is given by $R_{AB} = 3/2 - 3/8r_E + r_E/2$ for $r_E < 3/2$ and by $R_{AB} = 3 - 3/2r_E$ for $r_E \geq 3/2$. The figure also shows the boundary for SW ≥ 0. This coincides with R_{AB} for $r_E < 1.266$ and equals $\hat{R}$ for $r_E \geq 1.266$, where $\hat{R}$ solves $SW = qR - q^2 - (1 - k^{BS}) = 0$.

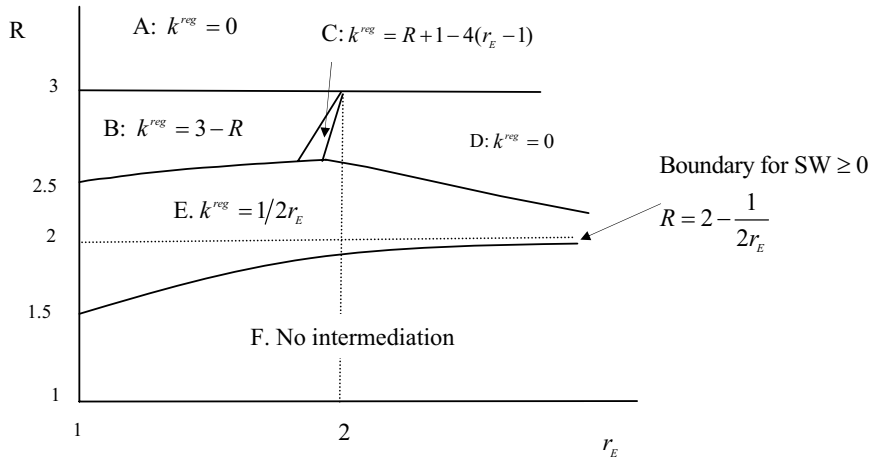

Figure 6: Regulatory solution with competition and deposit insurance. The figure shows the level of capital in the regulatory solution (k^{reg}) for the case of competition and deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes six regions: Region A, as defined by $R \geq 3$, where $k^{reg} = 0$; Region B, as defined by $R_{BC} \leq R < 3$ and $R_{BE} \leq R < 3$, where $k^{reg} = 3 - R$; Region C, as defined by $R < R_{BC} < 3$, $R_{CE} \leq R < 3$ and $R_{CD} \leq R < 3$, where $k^{reg} = R + 1 - 4(r_E - 1)$; Region D, as defined by $R < R_{CD} < 3$ and $R_{DE} \leq R < 3$, where $k^{reg} = 0$; Region E, as defined by $R_{EF} \leq R$, $R < R_{BE}$, $R < R_{CE}$ and $R < R_{DE}$, where $k^{reg} = 1/2r_E$; Region F, as defined by $R < R_{EF}$, where there is no intermediation. The boundaries between the regions are as follow: $R_{BC} = 2r_E - 1$, $R_{BE} = 3 - 1/2r_E$, $R_{CE} = r_E + \sqrt{r_E - 8r_E^2 + 10r_E^3 - 3r_E^4}\,/r_E$, $R_{CD} = 4r_E - 5$, $R_{DE} = \left(5\sqrt{r_E} + 2\sqrt{3 + r_E}\right)/3\sqrt{r_E}$, $R_{EF} = 2 - 1/2r_E$. The proof of Proposition 10 contains the intersection points between the boundaries.

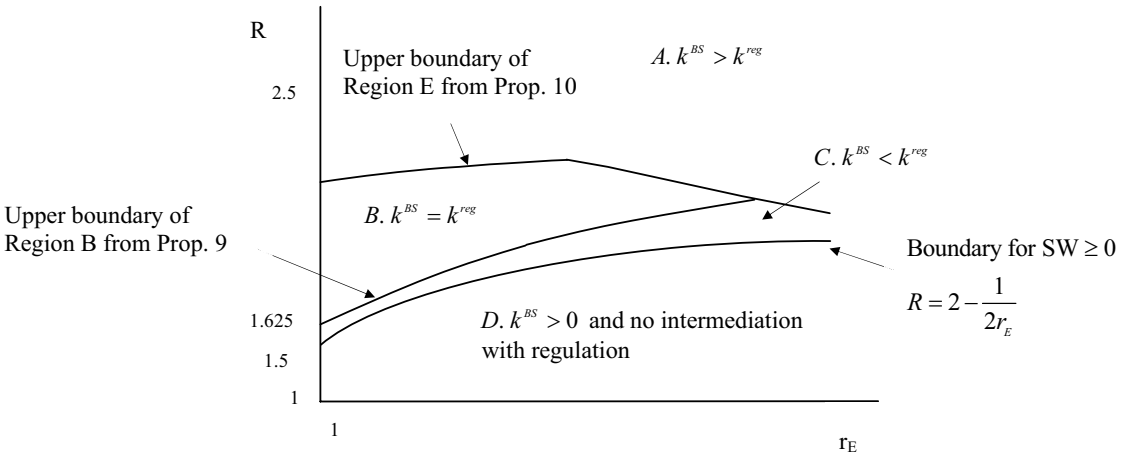

Figure 7: **Comparison of market and regulatory solution with competition and deposit insurance**. The figure compares the levels of capital in the market solution (k^{BS}) and regulatory solution (k^{reg}) for the case of competition and deposit insurance as a function of the cost of equity r_E and of the project return R. The figure distinguishes four regions: Region A, where $k^{BS} > k^{reg}$; Region B, where $k^{BS} = k^{reg}$; Region C, where $k^{BS} < k^{reg}$; and Region D, where $k^{reg} > 0$ and there is no intermediation with regulation. Region A exists for $R \geq R_{BE} = 3 - 1/2r_E$, $R \geq R_{CE} = r_E + \sqrt{r_E - 8r_E^2 + 10r_E^3 - 3r_E^4}\,/r_E$, and $R \geq R_{DE} = \left(5\sqrt{r_E} + 2\sqrt{3 + r_E}\right)/3\sqrt{r_E}$; Region B exists between $R < R_{BE}$, $R < R_{CE}$, $R < R_{DE}$, and $R \geq \hat{R}$ where $\hat{R} = 3/2 - 3/8r_E + r_E/2$ for $r_E < 3/2$ and $\hat{R} = 3 - 3/2r_E$ for $r_E \geq 3/2$. Region C exists for $2 - 1/2r_E \leq R < \hat{R}$; and Region D exists for $R \geq 2 - 1/2r_E$. The proof of Proposition 11 contains the intersection points between the boundaries of Regions A, B and C.

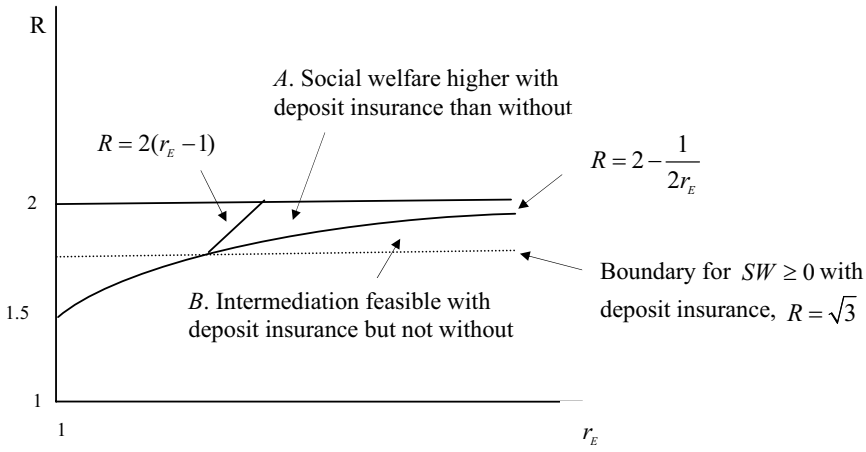

Figure 8: **Comparison of the market solution in the case of monopoly with and without deposit insurance**. The figure compares the market solutions in the case of monopoly with and without deposit insurance. The figure highlights two regions: Regions A, defined by $R < 2(r_E - 1)$, $R \geq 2 - 1/2r_E$, and $R < 2$, where social welfare is higher with deposit insurance than without; and Region B, defined by $\sqrt{3} \leq R < 2 - 1/2r_E$, where intermediation is feasible with deposit insurance but not without. The intersections between the boundaries are discussed in Section 5.3.